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ABSTRACT

This report describes the Urban Economics Program at the University of California, Santa Barbara; presents copies of research reports on public policy developed by program participants; and includes summaries of lectures on efficient pricing, microeconomics, mathematical programming, production function, political decision-making, marginal utility of income, and consumer's surplus. Objectives of the program are, generally, to train students to understand and work toward solving urban problems of the 1980's and, specifically, to produce urban specialists skilled in policy analysis and resource allocation. The program is structured so that students participate in a six month internship with a state or local agency in addition to more traditional lecture and research activities. A master's essay on the topic analyzed during internship is required for program completion. Feedback regarding the program's effectiveness indicates that the program has been successful in meeting the needs of both graduates and employers. Program developers believe that this success, in large part, is due to the combined program emphasis on rigorous skill development in areas including budgeting, policy analysis, and economic forecasting, and on the internship experience which allows students to develop and carry out projects of practical significance to employing agencies. (DB)

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FINAL PROJECT REPORT

AN URBAN EXTENSION: SOME INNOVATIONS

National Science Foundation Award Number

SED 73-10322 A05

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Community and Organization
Research Institute
University of California
Santa Barbara, California 93106

February 1980

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DEC 1 2 1980

Research Reports in Public Policy

Urban Economics Program
University of California
Santa Barbara, CA

The reports in this series are based upon research conducted by students in the Urban Economics Program. Most often, the research project was carried out during the course of a student internship for a public or private agency. All reports were selected and edited by Urban Program Faculty. The purpose of this report series is to disseminate, to a wide audience of public and private sector agencies involved in policy analysis, results of the application of social science methodologies to practical social problems.

RESEARCH REPORTS IN PUBLIC POLICY

Number

1 William Lee, "Public Park Acquisition: The Saticoy Golf Course," October 1975.

2 Robert A. Leiter, "Fiscal Effects of Residential Growth: An Analytical Model with Comparative Case Studies," October 1975.

3 George E. Goldman and Anthony Nakazawa, "An Input-Output Model of Santa Barbara County, California: With an Emphasis on Agriculture," November 1975.

4 Mary Streitwieser Jones, "A Municipal Tax Revenue Forecasting Model: The City of San Buenaventura," February 1976.

5 Howard Buchalter, "Land Use Alternative Using Input-Output Analysis," April 1976.

6 Dennis Muraoka, "Allocation of Space Requirements for a Local Government," April 1976.

7 Dennis Muraoka, "The Effects of Inflation on Local Government Expenditures," April 1976.

8 David R. Branchcomb, "Burglary Prevention: An Investment Analysis of Residential Protection," May 1976.

9 Richard P. Fajardo, "Capital Budgeting: Guidelines for Procedures," July 1976.

10 John F. Jenkins-Stark, "Population Forecasting and the Age-Structure: A Survey," September 1976.

11 Edward W. Kleeman, "Pricing Commercial Services to Municipal Tenants," September 1976.

RESEARCH REPORTS IN PUBLIC POLICY
(continued)

Number

12 Kenneth Miller, "An Intertemporal Cross-City Comparison of Single Family Housing Prices," April 1977.

13 Robert Dye, "Estimating the Impact of Resource Use Alternatives Employing Input-Output Technique: A Case Study," April 1977.

14 Jeffrey Newton, "Application of Linear Programming Analysis to Water Resources Planning for Agriculture: A Study of the Santa Maria Valley, California," May 1977.

15 Patrick King, "Oxnard Beach Park Study: A Benefit-Cost Analysis," March 1978.

16 James Kent, "Examining the Ventura Housing Market Via Linear Regression Techniques," March 1978.

17 Gail Ryff, "Revenue and Expenditure Forecasting Model for the City of Oxnard," March 1978.

18 Jeff D. Vitucci, "Environmental Impacts of Economic Development: An Input-Output Approach," May 1978.

19 Richard E. Gress, "The Relationship of Reappraisal Frequency and the Equitable Distribution of the Property Tax," May 1978.

20 Steven M. Edison, "An Economic Analysis of Hospital Costs: The Case of Maternity Services in California," November 1978.

21 Luigi F. Pinna, "An Application of Input-Output Techniques in Projecting Regional Manpower Requirements: Fresno County, California," January 1979.

22 Rose Gutierrez, "Fuel Management Options for the Santa Barbara Front," August 1979.

RESEARCH REPORTS IN PUBLIC POLICY
(continued)

Number

23 Kenneth M. Parris, "Municipal Government Revenue Sources in Post Proposition 13 California (Alternatives for Local Policy Makers to Finance Municipal Services)," August 1979.

24 Roy Callahan, "Otay Mesa East: A Comparative Fiscal Impact Analysis (Abridged)," November 1979.

PART III

Section c

DATA ON COLLABORATORS

This section contains: a list of all those who have directly collaborated in developing and operating the program since its inception, and their status with the program.

URBAN PROGRAM COLLABORATORS

Faculty

Perry Shapiro	Professor of Economics
Robert T. Deacon	Associate Professor of Economic
W. Douglas Morgan	Associate Professor of Economics
Donald R. Winkler	Assistant Professor of Economics
William Comanor	Professor of Economics
Jon Sonstelie	Assistant Professor of Economics
Vinod Agarwal	Assistant Professor of Economics
Thomas Anagnason	Assistant Professor of Political Science
John Moore	Associate Professor of Political Science
Biliana Cicin Sain	Assistant Professor of Political Science
Alan J. Wyner	Associate Professor of Political Science
Frederick Patrick	Lecturer in Economics

Graduate Students

Richard Fabrikant	Assistant II
Richard Young	"
Carl Perrelli-Minetti	"
Ennis Rosamond	"
Thomas Thorpe	"
Robin Zaft	"
Jonathan Smollen	"
Scott Beam	"
Subash Ray	"
Terry Malosh	"
William Viergever	"

PART III

Section e

DESCRIPTION OF PROJECT AND RESULTS

Included in this section are: a general description of the Urban Economics Program at UCSB; a collection of information on program details and promotional materials; a list of students, internship positions, occupations, and research projects; and a list of public and private sector agencies that have cooperated in implementation of the program.

Lists of students and agencies are included in Appendix 1 to this section. Urban Program and course information are included in Appendix 2 to this section.

URBAN ECONOMICS PROGRAM OPTION

A. Program Description

The Urban Economics Program is designed to train students to meet and solve the urban problems of the 1980's. The program is housed in the Department of Economics, University of California, Santa Barbara, and combines a carefully designed program of study in resource allocation theory and methods from the Economics Department, with political decisionmaking and background obtained in specific courses from the Department of Political Science. The program aims to develop an urban specialist (similar to the agricultural extension expert) who can bring to local governments the expertise concerning resource allocation and urban policy analysis that are found in contemporary Economics and Political Science.

The schedule of formal coursework offered by the program has been structured to emphasize practical applications of theory and the development of specific analytical tools. Following its inception in November of 1972, development of the Urban Program was aided by a grant from the National Science Foundation to develop new courses and an overall program structure. Basic graduate courses in economic decisionmaking, public finance and urban economics have been developed are are fully operational. In addition, special courses in public sector accounting, urban and regional modelling, economic forecasting, and computer skills have been devised to augment the quantitative aspects of our program. With the assistance of the Political Science Department, new courses in urban public administration are being offered and are a part of the Urban Program's required schedule of courses. We also encourage students to take additional elective courses in such fields as Political Science, Sociology, Geography, Environmental Studies, and

Computer Sciences. (See Appendix 2 for further detail.)

Aside from the multidisciplinary nature of our curriculum, the most innovative feature of the Urban Program is a required six-month internship, typically with a state or local agency. (See Appendix 1 for an exhaustive list of agencies participating in our internship program.) Internships are arranged during Spring quarter (the third quarter of course-work) and students begin internship work in mid-Summer. Student interns are enrolled in University extension, and their work is closely supervised by the program director. The internship, and the practical experience it offers, is of central importance in attracting students to our program, as opposed to others. Upon completion of all coursework and required internship activities, students return to campus to write a master's essay based upon the application of their training during the internship. The degree is conferred after successful defense of the essay in an oral examination.

Students who complete the program possess a variety of skills which have proven to be in demand by the State and local public sector. Important among these is the ability to develop and estimate econometric models for purposes of forecasting (e.g., public sector revenues and outlays), and the skill required to construct analytical models of regional economic activity for use in policy formulation and for hypothesis testing. In addition to statistical skills, public agencies often call upon our students to perform economic analysis of proposed public programs. Here, their formal training in methods of benefit cost and cost effectiveness analysis have proven highly valuable. Other very useful analytical abilities are in applications of linear programming to resource allocation problems, as well as input-output and economic base analysis for studying regional economic development. On balance, our students have fared well in their ultimate careers because they can offer their employers a knowledge of, and <u>immediate ability to apply</u>,

modern concepts in economic and political analysis as they relate to the urban environment.

The success of the program in developing and maintaining students' interest in the public sector has been outstanding. Of the students graduated, fully 58 percent have chosen positions in the public sector, while two students have returned to graduate work in economics. A further 32 percent have chosen employment in the private sector, primarily in research, supplying information and consulting services to urban and regional governments. Thus a large percentage has assumed leadership and management responsibilities associated with the public sector. (Appendix 1 provides a complete listing of students, and their first or current occupations.) Considering the high retention rate of past Urban Program students within the public sector, we fully expect that future graduates to have a comparable record of public service.

Upon entering the job market, Urban Program graduates possess three distinct advantages when compared to graduates of most competing programs. These are (1) the actual M.A. degree in urban economics emphasizing budgeting, allocation and quantitative tools; (2) the six months practical experience in local government where the program encourages all types of training activity (report writing, analysis, public presentation); and (3) a master's paper prepared on the problem area studied during their internship, illustrating the student's writing and analytical ability. Although there is no formal job placement arrangement, the program keeps in touch with the Western Governmental Research Association's monthly job listings, makes available the publication Job Openings for Economists, and fully utilizes the University of California's job placement center. To date, our graduating students have had very little trouble obtaining good entry level positions. (See Appendix 1 for examples).

Recruitment and selection procedures of all candidates for the Urban Economics Program are handled by the Department of Economics following regular University of California graduate admission procedures. The graduate committee in the Economics Department, of which the director of the Urban Program is a member, oversees the selection process. The basic standards of the University of California for graduate admission (a bachelor's degree with a minimum G.P.A. of 3.0 in undergraduate work) are observed at all times. In addition, students are encouraged to submit G.R.E. (Graduate Record Examination) scores for consideration by the graduate committee. This information is helpful for borderline cases. We also scrutinize the student's letter of application for an indication of strong desire to work in the public sector. Although the program is one of graduate study in Economics, the baccalaureate major of the incoming student does not have to be in Economics. Many of our most successful candidates come from such diverse undergraduate backgrounds as political science, dramatic art, English and French, as well as journalism. For those incoming students who have had incomplete training in the analytical skills required for Economics, a special admittance procedure is used in which students obtain the necessary background in statistics, quantitative methods, calculus, and intermediate microeconomics. Students using this option find that one or two quarters of preliminary work prior to beginning the graduate program is extremely useful.

As an option within the Department of Economics, the Urban Economics Program enjoys the full support and cooperation of the department chairman as well as the Graduate Dean at the University of California, Santa Barbara. The University and the Department have devoted resources to this program primarily because it is seen to fill a need for entry level management-

administrator personnel who are versed in the areas of economics and quantitative methods. The Urban Economics Program, with its judicious use of both resource allocation and political administration courses, definitely meets this need. The primary test of continuing support for graduates of this program is the substantial interest that local governments have shown toward our graduates. Many former students have continued to work as analysts, and in other management capacities, for their government internship employers. We have also found there is a great demand for our graduates in cities in the Tri-County area (San Luis Obispo, Santa Barbara and Ventura Counties, California). Several government agencies, such as the cities of Oxnard and Ventura, and the Cooperative Extension office in Santa Barbara, have returned each year to the Urban Program for interns to staff particular programs.

By way of evaluation of the program's effectiveness we have, to date, primarily relied upon the market test, i.e., the ability of our graduates to obtain public sector positions for which they were specifically trained. Appendix 1 documents the vocations that recent graduates have undertaken and represents the results of this test. We have also kept close contact with graduates of our program and have, from time to time, asked them to informally evaluate particular courses in the program with respect to their current needs on the job. During the last four years, this has resulted in some modifications, particularly in the area of specialized topics and subject matter to be included in certain Economics classes.

A further indication of the success of the program is reflected in the fact that twice, during the last four years, our program has been allocated student fellowship support from the Public Service Fellowship Program (U.S. Office of Education). In order to obtain current feedback and interaction with actual governments, the Urban Program has, for the last four years, conducted an urban seminar series where individuals

from both public and private sectors, come to campus to discuss their particular activities and problems associated with their agencies. Past participants include the Santa Barbara County Assessor, the Director of the Santa Barbara Metropolitan Transit District, representatives of the Ventura County Council of Governments, the Tri-County Area Agency on Aging, Ventura County Corrections Office, and other officials from local city and county governments. These seminars allow important, though informal, two-way communication between the Urban Program and the sectors of society it seeks to serve.

As noted earlier, part of the degree requirement is preparation of a master's paper on the topic analyzed during the internship phase of the program. To insure community feedback and to disseminate the work of our students over a wider audience, a selection of these master's papers have been published by the program in a series entitled Research Reports in Public Policy. These Reports have been placed in major public and university libraries, and judging from our mail requests, are well received throughout California and other states. Thus, the information and approaches to problem solving initiated by the urban students are made available to a wide number of public service agencies.

B. Curriculum

Students enter the Urban Program in Fall Quarter (beginning approximately September 25) and remain in the program for a minimum of six consecutive quarters, or the equivalent of two academic years. Since the program operates during summer, students who maintain normal progress are able to complete their studies in 18 months (i.e., by the end of Winter Quarter of the second year). Depending upon the scope and degree of difficulty of individual M.A. thesis projects, however, many students find it necessary to remain in the

program an additional quarter or two to complete their thesis research. The sequence of coursework, internship and research phases of the program are described in detail below.

Although the course of study and set of academic requirements for the program have been fully established since 1972, the exact content of the curriculum has been allowed to evolve in response to the expressed needs of our students and their prospective public sector employers. In structure, the formal coursework phase consists of three quarters academic work on campus, Fall, Winter and Spring, in which the student takes courses in microeconomic theory, quantitative methods, and special field courses in both economics and political science. (Details of the general program and specific courses required for students in 1979-1980 are found in Appendix 2.) The core of the program consists of economic decision-making, Economics 205A, B and C. In addition, quantitative methods beginning with Economics 5 for those students who have had no prior statistics training, and ending with Economics 140, economic forecasting, is required. Economics 141C and 245A are available for those students who wish to continue the quantitative aspect of their training in subsequent quarters. (See the University catalogue for course details.) The sequence also includes an introduction to computer programming, which the students have found valuable in actual public service work. Another series of courses includes those making use of the tools learned. These include public finance, Economics 230A; urban economics, Economics 220B; urban and regional analysis, Economics 123; and Political Science 181 and 295, urban public administration. The above constitute the key field courses which are required of all urban program students. In addition, there are a number of courses with which the students may supplement his or her program depending upon prior background and interest. For example, Environmental Studies teaches Environmental Impact Analysis (E.S. 165A, B) a series of

environmental planning courses. The UCSB Department of Geography teaches courses in economic geography, and Political Science has a set of courses available to increase the student's understanding of the political aspects of policy analysis. (Selected offerings for the year 1979/80 are found on the second page of Appendix 2.)

Several of our courses are recent innovations, undertaken to respond to the needs of our students "on the job." The third quarter of micro-economics, Economics 205C, is a course in which students are assigned an important practical problem currently being faced by a local agency. Under the instructor's direction, the students are guided through a program of original economic and statistical research aimed at solving this problem. This course was first offered in Spring 1977 and is now a part of our regular curriculum. Also, two "special topics" courses (Economics 594) were instituted in 1976 and 1977. One of these is a "user oriented" computer class that emphasizes use of remote terminals and text editing programs, job control language for using data tapes, and statistical software packages. The other is a non-credit (though required) seminar series in which representatives of state and local government agencies are invited to speak to our students on the needs and expectations of the public sector.

Several of our current students include individuals who have been engaged in public service careers for some time, but who wish to further their education by completing the Urban Economics Program. Being employed full-time, it is often difficult for these persons to attend regularly scheduled courses on campus. As a result, the Urban Program made videotapes of classroom lectures in our Urban and Regional Modeling course (Economics 123) and made them available for part-time students employed in Ventura County.

C. Internships

At the end of the first academic year, the regular urban M.A. student is ready for a six-month internship over the Summer and the following Fall quarters. Throughout this period, students are in close contact with their faculty advisers, as well as the program director. All interns return to campus once every three or four weeks to report in group session the results of their work to date. The use of faculty members from the Economics and Political Science Departments during this very crucial time is the key to the effectiveness of the internship program. They provide valuable guidance and consultation to students during the formulation and completion of tasks for the internship employer. This often results in a three-way communication involving the student intern, the local public agency employer, and program faculty. One indirect benefit of this is that it keeps the faculty up-to-date on the needs and desires of local public agencies.

Perhaps the only way to accurately convey the breadth and richness of practical experience made available to our students through the internship is to briefly describe a few of the projects in which our recent cohorts of students have been engaged. One student recently completed work for the Community Development Department in the City of Lompoc to assess the fiscal impacts of commercial and residential growth in a currently undeveloped portion of the city. The results of this analysis will play a key role in the formulation of that city's general plan and near-term future zoning policies. Another student is working for the City of San Diego on a similar project. In this case, the purpose is to study

the fiscal impacts of developing a major international airport in a currently undeveloped area. Two of our current interns are assessing the fiscal impacts of a potential annexation decision for the City of Ventura. Another is working on a "benefit assessment" model which will become the principal funding instrument for the Ventura County Flood Control District. Other students have been involved in studies of manpower allocation, capital budgeting, nutritional programs for senior citizens, implementation of zero base budgeting, and other projects implemented by local agencies in California.

It is important to emphasize the fact that these interns are given, by their employers, direct responsibility for developing and carrying out projects that are of major practical significance to the employing agencies. Students from the Urban Economics Program are viewed as a valuable resource by agencies that have had contact with the program.

As noted above, the final phase of the program consists of writing an M.A. essay on the topics analyzed during the internship. Students are assigned individual thesis advisors from among the faculty of Economics and Political Science Departments. In this time period students may also take additional elective courses.

D. Summary

Those who have participated in the Urban Economics Program feel that it has been highly successful in meeting its overall goal of facilitating the use of tools and concepts from modern Economics, Political Science, and Quantitative Methods toward the solution of public policy problems in the urban environment. In large measure, this success can be attributed to the philosophy of cooperative education embodied in the program's structure, and to the degree of direct involvement and participation that the program has sought and received

from the State and local public sector in California. We believe that the support granted to develop the Urban Economics Program represents a sound investment in better public management, and one that will continue to pay rewards in the decades to come.

PART III

Section e

Appendix 1

Appendix 1

URBAN PROGRAM STUDENTS

Fiscal Year 1972/73

1. Howard Buchalter
   - Internship employer: Ventura County Planning Department
   - Research project: "Land Use Alternatives Using Input-Output Analysis"
   - Occupation: Analyst, Ventura County Planning Department

2. Robert De La Cruz
   - Internship employer: City of Oxnard Finance Department
   - Research project: "Oxnard Municipal Golf Course Feasibility Study"
   - Occupation: Analyst, Oxnard Finance Department

3. Donald Knight
   - Internship employer: City of Santa Barbara Parks and Recreation Department
   - Research project: "A Study of Users' Preferences for Alternative Public Recreation Facilities"
   - Occupation: Director, Department of Recreation, City of Santa Barbara

4. William Lee
   - Internship employer: City of Ventura Budget Department
   - Research project: "Public Park Acquisition: The Saticoy Golf Course"
   - Occupation: Economist, Stanford Research Institute

5. Richard McGee
   - Internship employer: City of Pismo Beach
   - Research project: "Revenue Analysis and Forecasts for the City of Pismo Beach"
   - Occupation: Analyst, County of Tulare, California

6. Miriam Kadansky Mack
   - Internship employer: City of Ventura Budget Department
   - Research project: "San Buenaventura Beach Transfer Study"
   - Occupation: Assistant to City Manager (Program Evaluation), City of Ventura

7. William Matteson
   - Internship employer: City of Camarillo
   - Research project: "Economic Analysis for the City of Camarillo, California"
   - Occupation: Economist, ESRI (Environmental Systems Research Institute), Redlands, California

8. Anthony Nakazawa
   - Internship employer: City of Santa Barbara Police Department
   - Research project: "An Input-Output Model of Santa Barbara County, California: With an Emphasis on Agriculture"
   - Occupation:

9. Howard Rickard, Jr.
   - Internship employer: Santa Barbara County Sheriff's Department
   - Research project: "Sheriff's Patrol Manpower Allocation"
   - Occupation: County of Ventura Unified Corrections

10. Phillip Sanderson
    Internship employer: Ventura County Planning Department
    Research project: "Land Use Alternative Using Input-Output Analysis"
    Occupation: Regional Analyst, Vancouver, B.C.

11. Frederick Schremp
    Internship employer: Santa Barbara County Planning Department
    Research project: "An Econometric Forecasting Model for Santa Barbara County
    Occupation: Regional Representative, Lincoln National Sales Corporation, Florida

Fiscal Year 1973/74

12. Carl Branstrom
    Internship employer: Santa Barbara County Mental Health Administrative Offices
    Research project: Did not complete
    Occupation: Program Analyst with Santa Barbara County Mental Health

13. Jacqueline Cattani
    Internship employer: General Research Corporation
    Research project: "Parametric Economic Impacts of Electric Cars in Los Angeles
    Occupation: Partner in SysteMetrics, Inc., Santa Barbara

14. Dan Drazich
    Internship employer: Office of the Auditor, County of Santa Barbara
    Research project: "An Analysis of State Imposed Fiscal Limitations in Santa Barbara County"
    Occupation: Analyst, Department of Natural Resources, Fiji Islands

15. Richard Fajardo
    Internship employer: City of Oxnard, Finance Department
    Research project: "Capital Budgeting: Guidelines for Procedures"
    Occupation: Analyst, Finance Department, City of Oxnard

16. Mary Streitwieser Jones
    Internship employer: City of Oxnard, Building and Safety Department
    Research project: "A Municipal Tax Revenue Forecasting Model: The City of San Buenaventura"
    Occupation: Financial Analyst, City of Ventura

17. Conrad Langille
    Internship employer: Nevada Consumer Affairs Division
    Research project: "An Analysis of Milk Price Maintenance Laws in Nevada"
    Occupation: Financial Analyst, Nevada Consumer Affairs

18. Robert Leiter
    Internship employer: City of Ventura, Finance Department
    Research project: "Fiscal Effects of Residential Growth: An Analytical Model with Comparative Case Studies"
    Occupation: Analyst, City of Ventura Planning Department

19. Marco Lizarraga
    Internship employer: Ventura County Manpower Area Planning Council
    Research project: "Economic Study of the Manpower Training Project in Ventura County"
    Occupation: Analyst, Ventura County Manpower Area Planning Council

20. Richard Osaki
    Internship employer: Fresno County Planning Department
    Research project: "Fresno County Economic Study: A Proposed Format"
    Occupation: Analyst, Economic Development Office, Fresno County Planning Department

21 Granville Pool
    Internship employer: City of Oxnard Planning Department
    Research project: "An Economic Analysis of Growth Control Planning"
    Occupation: Analyst, Oxnard Planning Department

22. Benjamin Smith
    Internship employer: Santa Barbara County Assessor's Office
    Research project: "An Evaluation of the Water Moratorium in Housing Prices in the Santa Barbara SMSA"
    Occupation: Assistant Assessor, Santa Barbara County Assessor's Office

23. Robert Wolfe
    Internship employer: City of Ojai Planning Department
    Research project: "Economics and the Public Planning Process"
    Occupation: General Services Administration, Operational Planning Staff

Fiscal Year 1974/75

24. David Branchcomb
    Internship employer: Ventura County Criminal Justice Planning Board
    Research project: "Burglary Prevention: An Investment Analysis of Residential Protection"
    Occupation: County of Ventura Unified Corrections

25. David Busse
    Internship employer: County of Ventura Assessor's Office
    Research project: "An Application of the Multiple Regression Techniques to Assessing Commercial Property"
    Occupation: County of Ventura Assessor's Office

26. John Dimperio
    Internship employer: City of Ventura, Office of Research and Budget
    Research project: Did not complete
    Occupation:

27. John Jenkins-Stark
    Internship employer: General Research Corporation
    Research project: "Population Forecasting and the Age-Structure: A Survey"
    Occupation: Analyst, Pacific Gas and Electric

28. Darrell Joyner
    Internship employer: Santa Barbara County Cooperative Extension
    Research project: "Payments Capacity for Santa Barbara Agriculture"
    Occupation: State of California, Environmental Agency, Sacramento

29. Edward Kleeman
    Internship employer: Santa Barbara City Community Services Office
    Research project: "Pricing Commercial Services to Municipal Tenants"
    Occupation: Analyst, City of Coronado

30. Lynn Morecraft
    Internship employer: General Research Corporation
    Research project: "An Evaluation of the Housing Market for UCSB Students"
    Occupation: Analyst, General Research Corporation

31. Richard Lieberman
    Internship employer: General Research Corporation
    Research project: "An Economic Appraisal of Fire Protection Options for an Incorporated City of Isla Vista"
    Occupation: Principle, Tecolote Research Corporation, Santa Barbara

32. Dennis Muraoka
    Internship employer: City of Oxnard Finance Department
    Research projects: "Allocation of Space Requirements for a Local Government"
    "The Effects of Inflation on Local Government Expenditures"
    Occupation: Ph.D. student in Economics, UCSB

33. Carl Perelli-Minetti
    Internship employer: County of Los Angeles, Department of Urban Affairs
    Research project: "An Analysis of the Los Angeles Housing Market"
    Occupation: Ph.D. student at Hastings School of Law, UC

34. Gary Toeller
    Internship employer: County of Los Angeles, Department of Urban Affairs
    Research project: "The Costs and Benefits of the *Neighbors Against Burglars* Program in Simi, California
    Occupation: Sales Representative, Xerox Corporation

Fiscal Year 1974/75

35. Rosalie Calderone
    Internship employer: Santa Barbara County Assessor's Office
    Research project: "An Evaluation of the Water Moretorium in Housing Prices in the Santa Barbara SMSA"
    Occupation: Analyst, California Housing Project Agency, Los Angeles

36. Ruth Ann Collins
    Internship employer: South Central Coast Regional Commission, Santa Barbara
    Research project: "A Linear Programming Approach to Water Conditions as They Affect Agricultural Production"
    Occupation: Project manager, Carpinteria Local Coastal Plan

37. Robert Dye
    Internship employer: South Central Coast Regional Commission
    Research project: "Estimating the Impact of Resource Use Alternatives Employing Input-Output Technique: A Case Study"
    Occupation: City of San Diego Planning Department

38. William DeLoreto
    Internship employer: Association of Monterey Bay Area Governments
    Research project: "Economic Base Study for Monterey County, California"
    Occupation: Property Manager, DeLoreto & Associates, Santa Barbara

39. Steven Edison
    Internship employer: State of California Department of Health
    Research project: "An Economic Analysis of Hospital Costs: The Case of Maternity Services in California"
    Occupation: Analyst; SysteMetrics, Inc., Santa Barbara

40. William Hart
    Internship employer: City of San Juan Capistrano City Manager's Office
    Research project: "City of San Juan Capistrano: Five Year Budget Projections"
    Occupation: Consultant in private industry

41. Michael Kahoe
    Internship employer: City of Fresno Planning Department
    Research project: "Industrial Development Programs in Smaller Communities: Community Factors Which Affect the Type of Firm Attracted"
    Occupation: Analyst, City of Fresno, California

42. Kenneth Miller
    Internship employer: City of Ventura Research and Budget Office
    Research project: "An Intertemporal Cross-City Comparison of Single Family Housing Prices"
    Occupation: Analyst, Pacific Gas and Electric Company

43. Sanford Miller
    Internship employer: Santa Barbara County Planning Department Agricultural Commission
    Research project: "The Public Sector Revenue/Expenditure Framework of Land Uses in Santa Barbara County"
    Occupation: Public Utilities Commission, San Francisco

44. Margaret Magnus
    Internship employer: Tri-County Commission of Senior Citizens
    Research project: "Economic Evaluation of the Homemaker/Chore Services in Santa Barbara County"
    Occupation: Analyst, Kaiser Hospital, Los Angeles

45. Gail Ryff
    Internship employer: City of Oxnard Finance Department
    Research project: Revenue and Expenditure Forecasting Model for the City of Oxnard"
    Occupation: Financial Analyst, City of San Diego

46. Jeffrey Newton
    Internship employer: Santa Barbara County Agriculture Extension Service
    Research project: "Application of Linear Programming Analysis to Water Resources Planning for Agriculture: A Study of the Santa Maria Valley, California"
    Occupation: U.S. Agency for International Development, Wash., D.C.

47. Mark Wilkins
    Internship employer: Santa Barbara County-Cities Area Planning Council
    Research project: "Application of the Urban Institute's Housing Model to Santa Barbara County"
    Occupation: Not known

Fiscal Year 1976/77

48. Danvers Boardman
    Internship employer: Santa Barbara Fire Department
    Research project: Did not complete
    Occupation: Economist, City of Santa Barbara

49. Christopher L. Bush
    Internship employer: Santa Barbara County-Cities Area Planning Council
    Research project: Did not complete
    Occupation: Not known

50. Margaret L. Chan
    Internship employer: City of Oxnard Finance Department
    Research project: "Zero Base Budgeting for the City of Oxnard"
    Occupation: Analyst, City of Oxnard Finance Department

51. Barry Hyman
    Internship employer: City of Thousand Oaks Planning Department
    Research project: "Financial Plan for the City of Thousand Oaks, 1978-1984"
    Occupation: Economist, City of Thousand Oaks

52. James Kent
    Internship employer: City of Ventura Mayor's Office
    Research project: "Examining the Ventura Housing Market Via Linear Regression Techniques"
    Occupation: Analyst, Crown Zellerback, Inc., San Francisco

53. Patrick G. King
    Internship employer: City of Oxnard Parks and Recreation Department
    Research project: "Oxnard Beach Park Study: A Benefit-Cost Analysis"
    Occupation: Analyst, Pacific Power and Light

54. Peter Pelosi
    Internship employer: City of Oxnard Department of Water
    Research project: "Water Conservation: A Proposed Three Part Plan for the City of Oxnard"
    Occupation: Pacific Northwest Utilities Commission

55. Dan Shannon
    Internship employer: City of Oxnard Planning Department
    Research project: "The Use of Development Fees to Fund Capital Improvement Projects"
    Occupation: On leave of absence

56. Jeffrey Stone
    Internship employer: Point Mugu Naval Base
    Research project: "Converting Refuse to Energy: A Benefit Cost Approach to the Evaluation of Alternative Methods"
    Occupation: Analyst, Point Mugu Naval Base

57. Bert E. Thulien
    Internship employer: U.S. Forest Service, County of Santa Barbara
    Research project: "Resource Allocation and Government Policy: An Economic Perspective on Mineral Exploration and Domestic Livestock Grazing on Public Lands"
    Occupation: Research Analyst, Pacific Gas and Electric Company

58. Jeffrey D. Vitucci
    Internship employer: Fresno County Planning Department
    Research project: "Environmental Impacts of Economic Development: An Input-output Approach"
    Occupation: Research Analyst, Henningran, Durham and Richardson, Inc.

59. Jeffrey Warshauer
    Internship employer: California State Energy Commission, Sacramento
    Research project: "Socioeconomic Impacts of CERCDC's Appliance Efficiency Program"
    Occupation: Analyst, California State Energy Commission

Fiscal Year 1977/78

60. Roy Callahan
    Internship employer: Comprehensive Planning Organization, City of San Diego
    Research project: "Otah Mesa East: A Comparative Fiscal Impact Analysis (Abridged)"
    Occupation: Economist,City of San Diego

61. Elizabeth J. Clingman
    Internship employer: City of Lompoc Planning Department
    Research project: "A Cost Revenue Study for the Proposed Redevelopment in the City of Lompoc"
    Occupation: Private consultant

62. Rose Gutierrez
    Internship employer: U.S. Forest Service, Santa Barbara County
    Research project: "Fuel Management Options for the Santa Barbara Front"
    Occupation: Economic Analyst, Pacific Gas and Electric Company

63. James J. Jackson
    Internship employer: Ventura County Criminal Justice Department
    Research project: "An Evaluation of Alternative Processing for Juvenile Offenders"
    Occupation: Ventura County Criminal Justice Planning Board

64. James T. Moore
    Internship employer: The Pacific Plan
    Research project: "An Econometric Analysis of the Determinant of Housing Prices in Santa Clara County"
    Occupation: Analyst, Kaiser Health Plan, San Francisco

65. Kenneth M. Parris
    Internship employer: City of Oxnard Finance Department
    Research project: "Municipal Government Revenue Sources in Post Proposition 13 California (Alternatives for Local Policy Makers to Finance Municipal Services"
    Occupation: San Diego Gas and Electric Company, Rates and Valuation Department

66. Luigi F. Pinna
    Internship employer: Fresno County Planning Department
    Research project: "An Application of Input-Output Techniques in P Projecting Regional Manpower Requirements: Fresno County, California"
    Occupation: General Telephone Company, Los Angeles

67. Gerard J. Semons
    Internship employer: Tri County Commission for Senior Citizens
    Research project: "A Cost Benefit Analysis of Senior Citizen Nutrition Programs in Santa Barbara County"
    Occupation: Analyst, Tri County Commission for Senior Citizens

68. C. L. Spears, Jr.
    Internship employer: Tri County Commission for Senior Citizens
    Research project: "Optimum Siting for Senior Citizen Nutrition Sites in Santa Barbara County"
    Occupation: San Diego Gas and Electric Company

Fiscal Year 1978/79

69. Mark E. Armstrong
    Internship employer: Ventura County Planning Department
    Research project: "A Fiscal Impact Analysis of 'Island' Annexations in the City of Ventura"

70. Joseph Garma
    Internship employer: Pacific Gas and Electric Company, San Francisco
    Research project: "Forecasting the Impact of Solar Energy Upon Gas and Electric Demands in California"

71. William Harshbarger
    Internship employer: General Research Corporation
    Research project: "The Economic Feasibility of Home Recharge for Electric Vehicles"

72. Tony Mackey
    Internship employer: City of Ventura City Manager's Office
    Research project: "A Cost Revenue Analysis of Proposed Avenue Annexations in the City of Ventura"

73. P.I. Norman Stadem
    Internship employer: Ventura County Flood Control District
    Research project: "A 'Benefit' Tax Methodology for Flood Control Districts"

Appendix 1

LIST OF AGENCIES COOPERATING WITH THE
URBAN ECONOMICS PROGRAM

Note: The agencies listed below were directly involved with the Urban Economics Program either through employing student interns, participating in on-campus seminars, or requesting or commenting upon student research reports.

County of Santa Barbara
105 E. Anapamu St.
Santa Barbara, CA 93101

- Auditor's Office
- Planning Department
- Assessor's Office
- Sheriff's Department

County of Santa Barbara Cooperative Extension
140 E. Carrillo St.
Santa Barbara, CA 93101

County of Santa Barbara Mental Health Department
4444 Calle Real
Santa Barbara, CA 93111

City of Santa Barbara Community Services Department
1235 Chapala St.
Santa Barbara, CA 93101

City of Santa Barbara Police Department
215 E. Figueroa St.
Santa Barbara, CA 93101

Santa Barbara County and City Area Planning Council
1306 Santa Barbara St.
Santa Barbara, CA 93101

South Coast Regional Coastal Commission
120 E. De la Guerra St.
Santa Barbara, CA 93101

Tri County Commission for Senior Citizens
145 Santa Felicia Dr.
Goleta, CA 93017

General Research Corporation
5883 Hollister Ave.
Goleta, CA 93111

SysteMetrics
120 De la Guerra St.
Santa Barbara, CA 93101

Santa Barbara-San Luis Obispo Counties Professional Standards Review Organization
17 W. Carrillo St.
Santa Barbara, CA 93101

Santa Barbara-Ventura Counties Health Services Agency
P.O. Box 3966
Ventura, CA 93003

City of Ventura
P.O. Box 99
Ventura, CA 93001

- Planning Department
- City Manager's Office
- City Mayor's Office
- Research & Budget Office

County of Ventura Flood Control District
800 S. Victoria
Ventura, CA 93009

County of Ventura
501 Poli Street
Ventura, CA 93001

Manpower Area Planning Council
Criminal Justice Planning Board
Correctiions Services Agency

Ventura County Association of Governments
290 Maple Court, Suite 218
Ventura, CA 93003

City of Oxnard
P. O. Box 1192
Oxnard, CA 93030

Finance Department
Parks & Recreation Department
Water Department
Planning Department
Building & Safety Department

City of Thousand Oaks
1000 Oaks Street
P.O. Box 1496
Thousand Oaks, CA 93060

City of Camarillo
67 Palm Drive
Camarillo, CA 93010

City of Simi Valley
Crime Prevention Program
Police Department
Simi Valley, CA

City of Ojai
Planning Department
Ojai, CA

City of San Juan Capistrano
City Manager's Office
32400 Paseo Adelanti
San Juan Capistrano, CA

City of Pismo Beach
P.O. Box 3
Pismo Beach, CA

City of Lompoc
Planning Department
Lompoc City Hall
Lompoc, CA 93436

Association of Monterey Bay Area Governments
1011 Cass Street
Monterey, CA 93946

County of Fresno Planning Department
4499 E. Kings Canyon Rd.
Fresno, CA 93702

City of San Diego
Financial Management Department
202 C Street
San Diego, CA 92101

County of Los Angeles
Department of Urban Affairs
1543 Olympic Blvd., Suite 200
Los Angeles, CA

National Economic Research Associates
555 S. Flower St.
Los Angeles, CA 90071

U.S. Forest Service
42 Aero Camino
Goleta, CA 93017

Pacific Gas & Electric Company
Department of Economics & Statistics
77 Beale St.
San Francisco, CA 94106

California Department of Health
Maternal and Child Health Branch
2151 Berkeley Way, Annex #4
Berkeley, CA 94704

California State Energy Commission
Environmental Energy Assessment Division
1111 Hawe Ave.
Sacramento, CA 95825

Pacific Plan
(Loan Brokerage Firm)
San Jose, CA

State of Nevada
Consumer Affairs Division
Las Vegas, Nevada

PART III

Section e

Appendix 2

Urban Economics Program

informational and promotional materials.

Economics

Professors

[1]Alec P. Alexander, Ph.D., *UC Berkeley, economic development*
[4]William S. Comanor, Ph.D., *Harvard University, applied microeconomics, industrial organization*
Robert L. Crouch, Ph.D., *Essex, economic theory, money*
[4]M. Bruce Johnson, Ph.D., *Northwestern University, economic theory*
Clement G. Krouse, Ph.D., *UC Los Angeles, Finance, Economic Theory*
[2]Walter J. Mead, Ph.D., *University of Oregon, industrial organization, natural resources*
[3]Lloyd J. Mercer, Ph.D., *University of Washington, economic history, microeconomic theory*
W. Douglas Morgan, Ph.D., *UC Berkeley, Public Finance, Macroeconomic Theory*
Llad Phillips, Ph.D., *Harvard University, labor economics, econometrics, economics of criminal justice (Chairman)*
[3]John E. Pippenger, Ph.D., *UC Los Angeles, international finance, money*
Jati K. Sengupta, Ph.D., *Iowa State University, operations research, mathematical economics*
[4]Perry Shapiro, Ph.D., *UC Berkeley, urban and regional economics, economic theory*
Harold L. Votey, Jr., Ph.D., *UC Berkeley, economic development, international trade, economics of criminal justice*

Associate Professors

[4]Thomas F. Cooley, Ph.D., *University of Pennsylvania, econometrics*
[4]Robert Deacon, Ph.D., *University of Washington, resource economics, economic theory*
Stephen J. DeCanio, Ph.D., *Massachusetts Institute of Technology, economic history, econometrics*
H. E. Frech, III, Ph.D., *UC Los Angeles, health economics, microeconomic theory*
Anthony M. Marino, Ph.D., *UC Santa Barbara, Growth and Planning Theory, Development, Microeconomic Theory, (Visiting Assoc. Prof.)*
John Marshall, Ph.D., *Massachusetts Institute of Technology, urban and regional economics, economic theory*

Assistant Professors

George Borjas, Ph.D., *Columbia, human resources*
Jan K. Brueckner, Ph.D., *Stanford, Urban Economics, (Visiting Asst. Prof.)*
[3]Stephen LeRoy, Ph.D., *University of Pennsylvania, money, macroeconomics*
Neil A. Raymon, Ph.D., *University of Colorado, macroeconomics, mathematical statistics (visiting assistant professor)*
John Sonstelie, Ph.D., *Northwestern, state and local public finance*
Susan E. Woodward, Ph.D., *UC Los Angeles, economic theory, financial markets*

Professors Emeriti

Mortimer Andron, Ph.D., *University of Illinois*
J. Fred Halterman, Ph.D., *UC Berkeley*
William F. Kennedy, Ph.D., *University of Wisconsin*

Concerns of the department

The undergraduate programs in economics, business economics, and economics/mathematics are designed to serve several objectives. In combination with other courses in the College of Letters and Science, the majors provide the opportunity for general cultural and intellectual development. The majors are particularly useful in supplying basic training for students planning careers in business or government and offer valuable preparation for various professions including law, journalism, and accounting. The economics and economics/mathematics majors provide the opportunity to build a solid foundation for graduate study in either economics or administration. The business economics major provides the same opportunity with respect to graduate work in administration.

Department advising and publications

The Department's Undergraduate Academic Advisor, assisted by the Peer Counselors, is available for counseling in North Hall 3051, 961-2981, from 9-12, and 1-4. Any questions about courses, requirements, substitutions and petitions should be channeled there. The Department also has advisors in several specific areas: Business Schools, Economics/Mathematics major, Accounting, CPA and the Education Abroad Program. The Undergraduate Academic Advisor can direct students to these advisors.
Graduate students in need of counseling should contact the Graduate Secretary, North Hall, 3051, 961-2982, 9-12 and 1-4 PM.
Two handbooks for undergraduates are available with up-to-date department information. The general *Economics Handbook* published quarterly for majors and prospective majors, and the *Curriculum Guide For Economics Undergraduates* which answers questions most frequently asked by economics majors. Brochures regarding the M.A. and Ph.D. program in Economics and the M.A. programs in Urban Economics and Business Economics are also available.

[1]Sabbatical leave Fall 1979
[2]Sabbatical leave Fall and Winter 1979-80
[3]Sabbatical leave Spring 1980
[4]On leave, 1979-80

Bachelor of Arts—Economics

Preparation for the major

The following lower division courses are required: Math 1 or completion of 2 years of high school algebra, Economics 1 and Economics 2, and Economics 5. Economics 5 must be completed before upper division work. Upper division students transferring to the economics major from another major or another institution may take Economics 109 rather than Economics 1 and 2. Economics 109 may be taken concurrently with Economics 110, 104A, 101 or 105.

Only 2 units of credit will be allowed for Economics 109 if credit has already been given for Economics 1 or 2 or the equivalent.

Upper Division major

Thirty six upper division units in economics are necessary for the major. Three courses, Economics 100A or 104A, 100B or 104B, and 101 or 105, are required. The student may choose 24 units of other upper division economics courses with the restriction that Economics 109 does not count toward the upper division requirements. Credit will *not* be allowed for both 100A and 104A, or both 100B and 104B, or both 101 and 105.

Bachelor of Arts—Business Economics

Preparation for the major

Courses required as preparation for the major are the same as those for the Economics major except that Economics 3A and 3B or Economics 7A and 7B are additionally required. Credit will not be given for *both* Economics 3AB and Economics 7AB.

Upper Division major

Requirements for the business economics major are the same as for the economics major with the exception that at least four upper division electives must be selected from the following courses: Economics 102A, 116, 118A—B—C, 124, 131, 132A—B, 133, 134, 136A—B—C, 137A—B, 138A—B—C, 139A—B, 170, 172, and 175.

Bachelor of Arts—Economics/Mathematics

Preparation for the major

The following courses are required: Economics 1 and 2, Mathematics 3A—B—C, or 7A—B—C, or appropriate portions of 3S, 3D or appropriate portions of 3S, Mathematics 5A or 119A, and Mathematics 8. Upper division students transferring from another institution may substitute Economics 109 for Economics 1 and 2.

Upper Division major

Forty upper division units in economics and mathematics with a minimum of 16 units in each department, are required for the major. Economics 109, Mathematics 100A—B and Mathematics 133ABC do not count toward this upper division requirement. The following courses are required: Economics 104A—B, Economics 105, Mathematics 108A—B and either Economics 141A—B—C, or Probability and Statistics 120A—B—C. For breadth, further elective courses are recommended in applied fields of economics and in mathematics courses concerned with optimization. Students should consult closely with their advisor in the Economics or Mathematics Department concerning their upper division program.

Combination Social Sciences major

Students interested in obtaining a major in the combined social sciences, see listing under "Social Sciences."

Career opportunities

The undergraduate program in economics provides an excellent academic foundation for careers in both the public and private sectors. Courses in economics are recommended for students interested in law and journalism as well as business.

For **Graduate Training in Economics,** the Department recommends that students interested in graduate study in economics either elect the Economics/Mathematics major or take Economics 104A—B, and 105 (economic theory with a mathematical and pure theory emphasis) with electives chosen from the following courses: 102A, 102B, 102C, 141A—B—C, and 143.

Career in Public or Business Administration. It is recommended that students interested in preparation for a career in administration include the following economics courses in their programs: 3A-B or 7A-B, 116, 133, 134, 140, 141A-B-C, 143, 170, and 175. The following courses are also highly recommended for those students considering MBA programs: Mathematics 12A, Mathematics of Finance, Economics 118A-B-C, Legal Analysis for Business, and English 42, Practice in Writing.

Teaching credentials

Students who complete a major in economics may be eligible to pursue a California teaching credential. Specific details of State of California and University of California requirements for the USCB credential program are available from the Graduate School of Education, Education Advising Office, Room 1180 Phelps Hall.

Certain majors may require students contemplating a teaching career to complete specified courses within the major. These course requirements should be satisfied within the bachelor's degree program and prior to formal admission to the credential program.

Master of Arts—Economics

1. Admission Requirements

An undergraduate major in economics is not required for admission to the graduate program, but the Department does require that specific courses—particularly economic theory—be passed with distinction. At least one quarter of

calculus is also required. With the consent of the department, students with an inadequate undergraduate background in economics can be admitted, but they will be required to remedy any deficiencies by taking appropriate undergraduate courses. Graduate Record Examination scores are strongly recommended for the M.A. program, particularly for all foreign students, and are required for all M.A. students with a GPA less than 3.25. TOEFL scores (English language aptitude test) are required of *all* foreign applicants.

2. Degree Requirements

Plan IIA — 36 units of course work. At least 24 units must be in graduate (200 level) courses.

Economics 205A – B, Economics 204A, and Economics 140 are required. Economics 141A – B – C can be substituted for 140. With the approval of the graduate advisor a maximum of 8 units may be included from graduate or upper division courses in another department.

A comprehensive oral examination in economic theory and *two* elective fields is also required.

Plan IIB — 36 units of course work consisting of all the courses typically taken in the first year of the Ph.D. program. An elective field other than quantitative methods may be substituted for Economics 240 and 141ABC; in this case Economics 140 is required.

A comprehensive oral examination in micro- and macroeconomic theory and quantitative methods, or the elective field substituted for quantitative method, is required.

Plan IIA is designed for students who enter with an M.A. degree specifically in mind. Plan IIB is designed to allow students in the Ph.D. program to acquire an M.A. degree after they have taken an appropriate number of primarily Ph.D. courses and an oral examination.

There is no language requirement for the M.A. degree. A well-prepared student can obtain the M.A. degree in one year.

Option in Business Economics

The Business Economics option in the Master's Degree Program is offered to candidates interested in a career in applied economics for government and business.

The required core of the curriculum involves courses in economic decisions, economic forecasting, managerial accounting, the organization of industry, financial management and 2 electives from a group of related courses. Areas of emphasis in the Business Economics option are financial management, the organization of industry and economictrics and forecasting.

The well prepared student can complete this M.A. degree option in one year. The student who wishes to emerge from this program with both the B.A. and sufficient preparation to sit for the CPA exam, may accomplish *both* objectives concurrently.

Option in Urban Economics with Internship

The Urban Economics option in the Master's Degree Program offers a unique approach to the urban challenge. The program is problem oriented and highly flexible depending on the educational background of the student. The working philosophy of the program is to view the urban problem as one of resource allocation.

The first group of courses, which is the core of the program, is in economic decision-making.

URBAN ECONOMICS
PROGRAM SEQUENCE

	FALL	WINTER	SPRING	SUMMER/ FALL	WINTER
Economic Theory	Theory of the firm and Markets	Linear Programming Input-Output	Elective		Decision Theory or Elective
Policy Analysis and Implementation	Public Administration or Urban Politics	Public Expenditure and Revenue	Urban Economics		Seminar on Internship Experience
Tools	Statistics	Econometrics	Accounting		Elective
Emphasis			Elective	Internship	Elective
Laboratory (Computer Use)	Statistics	Econometrics	Accounting		Preparation of Master's Essay

The second area of emphasis deals with the analysis and implementation of public policy. Courses in both economics and political science are included in this set. These courses are designed to acquaint the student with the realities under which decisions are formulated.

The third class of courses deals with tools, such as statistics and accounting, that will be useful to the student in future employment. Additionally the student will be required to participate in a laboratory designed to provide the opportunity to practice newly acquired skills and to learn the techniques of modern computerized data manipulation and computation.

Depending on the student's preparation, courses are available that will accommodate the individual student's area of interest in the urban sector. These will be elective and will relate to such areas as urban and regional economics, environmental economics, economics of human resources relating to education, public health, criminal justice, labor problems, public finance, public administration, urban politics and appropriate courses in sociology, biology, physics and various areas of specialization in engineering relating to the provision of urban services and the control of the urban environment.

A six month internship in a local government provides on the job experience after the first three quarters of academic work.

The final requirement for the degree is a Master's Project, a report on research initiated by the student and dealing with a problem relevant to the internship and an oral examination. This consists of a report and oral examination on research initiated by the student and dealing with a problem relevant to the internship.

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Doctor of Philosophy—Economics

Requirements

1. Admission Requirements

An undergraduate major in economics is not required for admission to the graduate program, but the department does require that specific courses – particularly economic theory – be passed with distinction. At least one year of calculus is also required; prospective students, however, are advised to take as much mathematics as possible, particularly calculus and matrix algebra. With the consent of the department, students with an inadequate undergraduate background in economics can be admitted, but they will be required to remedy any deficiencies by taking appropriate undergraduate courses. Graduate Record Examination scores in quantitative and verbal aptitude are required for admission to the Ph.D. program. TOEFL scores (English language aptitude test) are required of *all* foreign student applicants.

2. Degree Requirements

For the Ph.D. degree, a course in Capital Theory and Uncertainty, plus four fields are required, two of the fields are specified: 1) economic theory and 2) quantitative economics. Two additional fields will be selected from a list of electives. With the Department's approval, one elective may be chosen from an outside discipline.

After one year of course work a well prepared student should be ready to take the written General Examinations in economic theory and quantitative economics.

Within a year of passing the written preliminary examinations the candidate is expected to submit a written dissertation proposal and defend it orally.

There is no language requirement for the Ph.D. Degree. A well prepared student can obtain the Ph.D. degree in three to four years.

Candidate in Philosophy (C.Phil.)

Requirements

On advancement to candidacy for the Ph.D. degree (i.e. after having completed the General Examinations, but before completing the dissertation), a student may petition for the award of the C.Phil. degree. This is specifically designated as a non-terminal degree. Eligibility for the C.Phil. degree is limited to a period of seven years following advancement to candidacy for the Ph.D. degree.

A well prepared student can obtain a C.Phil. degree in two years.

Economics

Lower Division Courses

1 • Principles of Economics-Micro (4) Crouch, Johnson [E1]
An introduction to microeconomic analysis. Economic theory related to demand, production, competitive and non-competitive product markets, input markets, and welfare. Applications of microeconomic theory including its use in evaluating and forming public policy. Economics 2 may be taken before Economics 1. (F,W,S)

2 • Principles of Economics-Macro (4) Morgan [E1]
An introduction to macroeconomic analysis. Analysis of income, employment, and price level. Applications of macro economic theory including its use in evaluating and forming public policy. (F,W,S)

3A-B • Accounting Principles and Practices (4-4) Bartyn
Introduction to accounting principles and practices. The elements of an accounting system and the recording of basic data. Applications in financial control accounting. Financial statement preparation and analysis. This course is prerequisite to all upper division accounting courses. (F,W,S)

5 • Statistics with Economic and Business Applications (4) DeCanio [E1]
An introduction to the analysis of economic data; elementary statistical methods and use of the computer. Topics will include basic probability theory, statistical inference and hypothesis testing, and regression.
Two lectures and a two hour seminar weekly. (F,W,S)

6 • Application of Mathematics in Economics (4) Staff [E1]
Prerequisites: Economics 1 and 2
An introductory survey of the application of mathematics in economics. Topics in economic theory are analyzed with the use of mathematical techniques from the calculus. Students who have taken Math 3A or Math 34A or the equivalent can not receive credit for Economics 6.

7A-B • Accounting Theory (4-4) Gudnason
An introduction to accounting theory and principles (which fulfills the accounting requirement for business economics majors). However, students who wish to become professional accountants should take Economics 3A-B (which emphasizes accounting practice) and not Economics 7A-B. Credit will not be given for both Economics 3A-B and Economics 7A-B. (F,W,S)

10FS • Freshman Seminar (3) Staff
A general introduction to economics taught in seminar fashion by members of the department. Not to be offered in 79-80.

Upper Division courses

100A • Microeconomic Theory and Policy (4) Sonstelie, Shapiro, Morgan [E1]
Prerequisites: Economics 1 and 2 or 109 and Econ 5.
Economic theory relating to demand, production and competitive product markets with emphasis on applications of theory. **Credit not given for both 100A and 104A.** (F,W,S)

100B • Microeconomic Theory and Policy (4) Johnson [E1]
Prerequisite: Economics 100A.
Economic theory relating to non-competitive product markets, input markets, and welfare with emphasis on applications of theory. **Credit not given for both 100B and 104B.** (F,W,S)

101 • Static Macroeconomics and Policy (4) LeRoy, Morgan [E1]
Prerequisites: Economics 1 and 2 or Economics 109, and Economics 5.
Contemporary analysis of income, employment, and price level and public policy using a static general equilibrium framework with emphasis on applications of theory. **Credit not given for both 101 and 105.** (F,W,S)

102A • Advanced Topics in Microeconomics (4) Sengupta [E1]
Prerequisite: Economics 100B or 104B.
Elements of linear programming, input output analysis and game theory.

102B • Dynamic Macroeconomics (4) Staff [E1]
Prerequisite: Economics 101 or 105.
Analysis of dynamic macroeconomic systems including economic fluctuations, growth and stabilization.

102C • Advanced Macroeconomics (4) Staff [E1]
Prerequisite: Economics 101 or 105.
Selected topics in short run and long run dynamic economic theory and policy.

103 • History of Economic Thought (4) Staff [E1]
Prerequisites: Economics 1 and 2 or 109.

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The history of economic thought in relation to its social setting from ancient Greece and Rome to Marxism and Marginalism in the nineteenth century.

104A • Microeconomic Theory (4) Cooley, Frech [E1]
Prerequisites: Economics 1 and 2 or 109, plus Economics 6 or Mathematics 34A and 34B.
Economic theory relating to demand, production and competitive product markets with emphasis on pure theory and use of techniques from the calculus. **Credit not given for both 104A and 100A.**

104B • Microeconomic Theory (4) Miyao, Sengupta [E1]
Prerequisite: Economics 104A.
Economic theory relating to non-competitive product markets, input markets and welfare with emphasis on pure theory and use of techniques from the calculus. **Credit not given for both 104B and 100B.**

105 • Static Macroeconomics (4) Marshall [E1]
Prerequisites: Economics 1 and 2 or 109, plus Economics 6 or Mathematics 34A and 34B.
Contemporary analysis of income, employment, and price level and public policy using a static general equilibrium framework with emphasis on pure theory and use of techniques from the calculus. **Credit not given for both 105 and 101.**

107 • Comparative Economic Systems (4) Frech [E1]
Prerequisite: Economics 100B or 104B.
Socialism, fascism, and capitalism contrasted with regard to economic decision-making, organization of production, mechanism of exchange, banking and investment, distribution of income, status of labor, international trade and public finance.

109 • Introduction to Economics (4) Staff [E1]
Not open to those who have taken Economics 1 and Economics 2. Economics majors may enroll in Economics 109 only if they have Upper Division standing. Serves as a prerequisite for Upper Division economics courses.
Only 2 units of credit will be allowed for Economics 109 if credit has already been given for Economics 1 or 2 or the equivalent. Majors are advised to take Economics 1 and 2 for a more thorough background for the major.
Intensive study of economic principles. (Does not count as Upper Division major elective.) (F,W,S)

110 • Contemporary Economic Problems (4) Staff [E1]
Current social economic problems will be analyzed, each by a qualified staff member. Topics may include the following: the economics of poverty, discrimination, war, monopoly, the stock market, gold, inflation-deflation, economic growth, and alternative economic systems.

111 • The Economic Foundations of Human Behavior (4) Crouch [E1]
Prerequisite: Economics 1 or 109 or permission of instructor.
A study of the system of forces which determine human behavior. Discussion of the economic, biological and psychological explanations of human behavior characteristics such as discrimination, hierarchy, competition, cooperation, aggression, acquisitiveness, etc. An interdisciplinary course drawing on source material from economics, as well as the fields of anthropology, biology, ethology and psychology.

112A • European Economic History to 1850 (4) Mercer [E1]
Analysis of the economic development of Europe from the Middle Ages through the English Industrial Revolution.

112B • European Economic History since 1850 (4) Mercer [E1]
Analysis of the economic development of Europe since the English Industrial Revolution.

113A • Economic History of the United States to 1900 (4) Mercer [E1]
Prerequisites: Economics 1 and 2 or 109.
A survey of U.S. economic development from colonial times to the end of the nineteenth century with emphasis on issues related to U.S. economic growth and public policy as it affected both growth and the distribution of income.

113B • Twentieth Century United States Economic History (4) Mercer [E1]
Prerequisites: Economics 1 and 2 or 109.
A survey of U.S. economic development in the twentieth century with emphasis on issues related to the growth, instability and distribution of income. The impact of public policy on economic growth, instability and income distribution will be an important theme of the course.

114 • Economic Development (4) Votey [E1]
Prerequisites: Economics 1 and 2 or 109.
Applications of economic theory to the problems of developing nations.

115 • Environmental Economics (4) Staff [E1]
Prerequisites: Economics 1 and 2.
Economic analysis of environmental decision-making. Determination of the optimum level of pollution. Examination of the concept of externalities, estimation of social versus private costs and benefits, common property resources, welfare theory and production theory applied to problems of pollution.

116 • Organization of Industry (4) Frech, Mead [E1]
Prerequisite: Economics 100B or 104B.
Analysis of competition, monopolistic competition, oligopoly and monopoly theories and practices.

118A—B—C • Legal Analysis for Business (4-4-4) Barrymore [E1]
Prerequisites: 118A is prerequisite for 118B and 118B is prerequisite for 118C.
A: The essentials of analysis of the law of contracts and their economic significance. (F)
B: An examination of the process of legal analysis of business relationships including agency, partnerships, and corporations. Includes study of the nature, formation and extent of agency, partnerships and corporations and comparisons between these various forms of business units and entities. It is recommended that 118A be taken before 118B. (W)
C: An analysis of the law of bailments, sales, emphasizing the Uniform Commercial Code and negotiable instruments including checks and promissory notes. (S)

120 • Urban and Regional Economics (4) Marshall [E1]
Prerequisites: 100B or 104B.
Economic analysis applied to current urban and regional problems.

121 • Real Estate and Housing Markets: An Introduction (4) Shapiro (Econ), Smith (Geog)
Prerequisites: None.
This course considers the structure of housing prices, the structure of the market, real estate finance, commercial and industrial real estate, supply and demand for housing and housing and the national economy and housing cycles.
Students are encouraged to take Geography 121 as a follow-up course.

122 • Natural Resource Economics (4) Mead [E1]
Prerequisite: Economics 100B or 104B.
Microeconomic theory and capital theory applied to problems of conservation and management of natural resources. Analysis of public policy with special emphasis upon energy resources and the energy crisis. Additional topics may include examination of water, fishery, and outdoor recreation resource management.

123 • Urban and Regional Modeling (4) Staff [E1]
Prerequisite: Economics 120 or permission of instructor.
Contemporary macroeconomic theory is applied as a means of description and analysis for regional economics. Practical applications (modeling) of input-output techniques and multiplier analysis will be studied.

124 • Business Ethics and Social Responsibility (4) Bremer [E1]
Prerequisites: Economics 1 and 2 or 109.
Application of ethics to the decisions of economic life, the responsibilities of individuals and economic organizations.

125 • Water Resource Economics (4) Mercer, Morgan [E1]
Microeconomic and capital theory applied to the problems of management of water resources. An analysis of public policy issues in the management of water resources. (S)

130 • Public Finance (4) Sonstelie [E1]
Prerequisites: Economics 100A and/or 104A and Economics 101 or 105.
Fiscal theory and policy. Incidence and effects of taxation, government expenditure programs and benefit-cost analysis.

131 • Fund Accounting - Accounting For Governments and Non-Profit Institutions (4) Macy
Prerequisite: Economics 136C.
Principles of fund accounting as used by all levels of government and by universities and colleges, hospitals, public schools, and research institutions operating on grants and other public support, and by charitable institutions.

132A—B • Auditing (4-4) Staff
Prerequisite: 136C.
Standard responsibilities, and control of audit

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engagements, internal control and procedural testing, objectives, reporting, and audit procedures with respect to the balance sheet and operating accounts, concluding the audit engagement, preparation of the audit report, and review of the audit engagement.

133 • Investments (4) Woodward [E1]
Prerequisites: Economics 5 or equivalent and Economics 100B or 104B.
Sources and demand for investment capital, salient characteristics of governmental and corporate securities, operation of security markets, determination of investment policy, and procedures for analysis of securities.

134 • Financial Management (4) LeRoy [E1]
Prerequisites: Economics 5 or equivalent and Economics 100B or 104B.
Analysis and management of the flow of funds through an enterprise. Sources and application of funds, types and sources of long term capital. Introduction to the supply of investment funds and the organization of capital markets.

135 • Monetary Economics (4) Pippenger [E1]
Prerequisite: Economics 101 or 105.
Survey of monetary theory, the banking system and the supply of money, monetary policy and current issues.

136A—B • Intermediate Accounting (4 4) Staff
Prerequisites: Economics 3B or permission of Director, Accounting Program, OR a "B" average in Economics 7A,B, plus permission of Director, Accounting Program.
The development of a more comprehensive knowledge of accounting principles and practice. Some of the topics covered in this course are: the recognition, analysis, and evaluation of business transactions having accounting significance; the recording, valuation, and presentation of the various principal asset, liability, and invested capital accounts; further practice in the preparation of the balance sheet and the income statement; principles basic to and preparation of the statement of changes in financial position; financial statement analysis; and specialized accounting topics. (F, W, S)

136C • Intermediate Accounting, Current AICPA Pronouncements (4) Staff
Prerequisite: 136B.
The course extends the work on accounting theory in 136B by focusing on an analysis of the original AICPA, FASB and SAS Pronouncements. Members of the accounting profession will be invited to moderate certain classes. (F, W, S)

137A—B • Cost Accounting (4 4) Staff
Prerequisite: Economics 136C.
Concepts and objectives of planning and control; information system and accumulation procedures; planning and control of factory overhead, materials, and labor; planning of profits, costs and sales through budgeting; controlling costs and profits through standard costs and gross profit analysis; cost and profit analysis.

138A—B • Tax Accounting (4 4) Staff
Prerequisite: Economics 3B.
Basic concepts of income taxation with respect to income and deduction; areas of special tax procedures pertaining to gains and losses from sales and exchanges, installment sales, depreciation and depletion methods, and losses; preparation of the tax returns for individuals; special tax procedures and preparation of income tax returns for partnerships, estates and trusts and corporations.

138C • Advanced Tax Accounting (4)
Prerequisite: Economics 138B.
Advanced concepts of income taxation. Advanced tax problems, including underfinancing, continuing losses, tax shelters, dividends, redemptions, liquidations, reorganizations, buy/sell considerations, carryovers, tax accrual reviews / accounting for FIT, U.S. taxation of multinational activities.

139A—B • Advanced Accounting (4 4) Staff
Prerequisite: Economics 136C.
Accounting for partnerships: formation and operation, dissolution and liquidation; special sales accounting procedures; installment sales, consignments, home and branch office; consolidations and accounting for fiduciaries, receiverships and estates and trusts.

140 • Introduction to Econometrics (4) Cooley [E1]
Prerequisites: Economics 1 and 2 and Economics 5 or equivalent.
A practical course in the development of economic models, analysis of specific functional forms, and the application of forecasting and estimation techniques. Emphasis is placed on the student's use of the computer facility as an aid in applying these techniques for the study of social and economic problems.

141A—B—C • Econometrics (4 4 4) Cooley, Phillips, Shapiro [E1]
Prerequisite: Mathematics 34A - B - C or equivalent.
The application of quantitative methods in economics. 141A will cover probability and its use in decision theory, distributions and their application to the distribution of income and firms, inference and hypothesis testing and their application in econometric estimation and model construction.
141B will continue with estimation covering the general linear regression model, Bayesian procedures, and applications of non parametric techniques.
141C will discuss specific problems which arise in the course of estimating economic models, such as: the use of dummy variables; heteroscedasticity; multicollinearity; autocorrelation and an introduction to simultaneous equation estimation.

143 • Mathematical Economics (4) Marshall [E1]
Prerequisites: Economics 104B and 105.
Application of mathematics to selected topics in micro- and macro economic theory.

150 • Labor Economics (4) Staff [E1]
Prerequisite: Economics 100B or 104B.
The impact of unions on wages, income distribution, employment and prices. The role of government in collective bargaining.

160 • Economics of Crime and Justice (4) Phillips, Votey [E1]
Examines social policy to minimize the losses to crime and the costs of crime control. Develops the economics of crime generation, law enforcement, prosecution, corrections and punishment.

170 • Managerial Accounting (4) Cadenhead
Prerequisites: Economics 7B or 3B.
Managerial Accounting is designed for students who desire to enter the field of management rather than Professional Accounting. The emphasis is on uses of accounting data internally by managers in setting plans controlling operations, and making management decisions. Cost accumulation for Product Costing, Cost Allocation for Planning and Control, Cost Behavior Patterns, Cost Volume Profit Relationships, Profit Planning, Control through Standard costs are typical of topics covered in this course.

171 • Senior Accounting Internship (1 4) Staff
Prerequisites: 136C, Senior standing with 3.0 or better GPA, interview with instructor.
This course provides senior accounting students the opportunity to gain further knowledge in the areas of accounting, auditing, and income tax, and the opportunity to gain practical experience in the management of an accounting firm. Credit will be given on a P/NP basis at the rate of 1 unit of credit for each 25 hours of internship at an accounting firm during a period not shorter than five weeks nor longer than ten weeks. Each student will prepare a written summary of the internship assignment at the end of the first five weeks, and again at the end of the quarter. Maximum credit not to exceed 4 units.

172 • Computer Based Accounting Systems (4) Barlyn
Prerequisites: Economics 136C, GPA 3.0.
Electronic data processing in the context of accounting, as tested in the AICPA's Uniform CPA examinations, through a study of hardware, software, and sample applications.

175 • Government and Business (4) Staff [E1]
Prerequisite: Economics 1 or 109.
Analysis of alternative public policies for maintaining competitive performance in the economy.

180 • International Trade (4) Votey [E1]
Prerequisite: Economics 100B or 104B.
Historical and contemporary trade mechanisms; international trade theory, trade and welfare.

181 • International Finance (4) Pippenger [E1]
Prerequisite: Economics 101 or 105.
International money and capital markets and their impact on the domestic and world economies; international financial institutions and policies.

192 • Field Research in Economics (4 12) Staff
Prerequisites: Upper Division status, 3.00 overall GPA, approval of project by faculty sponsor and Department Undergraduate Committee.
Directed field research on a topic in economics. No more than four units of Economics 192 may be counted toward the requirements for the major in Economics, Business Economics, or Economics/Mathematics.

194 • Group Studies (1 4) Staff
Prerequisites: Upper Division standing and admission by special arrangement.

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Intensive study and research on a topic in economics selected by the student with the guidance and approval of a faculty member. Subject to Departmental approval, students may repeat this course; however, only four units may count toward the major.

196H • Senior Honors Seminar (4) Staff
Prerequisite: Senior standing with 3.0 or better average in the major.
Advanced topics in economic theory and policy. Weekly seminar discussions led by various members of the economics faculty.

***199 • Independent Studies in Economics** (1-5) Staff
Admission by special arrangement. 199 courses are limited to no more than 5 units in one quarter and no more than 12 units total.

Graduate Courses

200A-B-C • Microeconomic Theory (4-4-4) Frech, Johnson, Phillips, Shapiro
A-B Methodology, theory of consumer behavior and demand, modern utility theory, exchange and markets, theory of the firm, mathematical programming supply and demand of factors, externalities. *C* General equilibrium and welfare economics.

201 • Advanced topics in general equilibrium and welfare economics.

202 • Advanced Topics in Economics Theory (1-4) Deacon, Mead, Miyao, Phillips
Reading and discussion of selected topics and recent literature in current economic theory. Specific material will vary from quarter to quarter. May be repeated for credit.

203A—B • History of Economic Thought (4-4) Staff
A: Analysis of the relationships between social conditions, economic theory, and economic policy from the medieval to the classical period. **B:** Analysis of the relationships between social conditions, economic theory, and economic policy from the neo-classical period to the present. Methodological problems including relationships to the sociology of knowledge and general intellectual history.

204A-B • Macroeconomic Theory (4-4) Crouch, LeRoy, Marshall, Morgan
A: Static macroeconomic theory. Classical, Keynesian and post-Keynesian theory of natural income and employment. **B:** Disequilibrium macroeconomic theory. Survey of disequilibrium theory, with emphasis on modelling price dispersion and search, and on fixed-price disequilibrium analysis. Additional topics may include investment theory, financial equilibrium and dynamic macroeconomics.

205A—B • Economic Decisions (4-4) Deacon, Shapiro
The course will establish the ideas and techniques of optimally allocating scarce resources. The student will learn the nature of objective functions and constraints in theory and through examples describing rational economic behavior of individuals, firms and public bodies.

205C • Economic Decisions (4) Staff
Prerequisite: Graduate Standing, Econ 205A-B and/or consent of instructor.
Linear and nonlinear programming and benefit cost analysis. Theory of intertemporal optimization and general equilibrium welfare analysis. Economic analysis of real public (or private) capital project will be required.

206 • Operations Research (4) Sengupta
Prerequisites: Econ 205A, Econ 205B or consent of the instructor.
Topics in applied methods of operations research selected from stochasing programming, statistical decision theory, inventory control and queuing.

211A-B • The Economic Foundations Of Human Behavior (4-4) Crouch
Theoretical analysis of human capital accumulation, the allocation of time, household production, and the family as a decision making unit with respect to non-market behavior. Application of the preceding to such topics as fertility, marriage, criminality, health, education, discrimination.

212 • Economic History Of Europe (4) DeCanio, Mercer
Issues in European economic history.

213 • American Economic History (4) DeCanio, Mercer
Issues in American economic history.

214A-B • Economic Development (4-4) Volley, Staff
A study of the special problems faced by the less developed countries and the initial conditions and economic mechanisms that must be taken into account in raising living standards. Topics considered include population growth, labor supply, capital accumulation, the use of foreign resources, and effects of technological change.

216A-B • Organization of Industry (4-4) Frech, Johnson, Mead, Krouse
Advanced topics in industrial organization and public policy.

220A—B • Urban and Regional Economics (4-4) Marshall, Shapiro, Sonstelie
A: The theory of city and regional economics. Economic theory when distance is taken as an important determinant of economic activity. **B:** Urban and Regional Policy. The application of theory to policy decisions.

230A-B • Public Finance (4-4) Deacon, Morgan, Shapiro, Sonstelie
A: Public goods, taxation and expenditure theory. **B:** Topics vary: public debt management and fiscal policy; advanced topics in public expenditure and taxation theory; analysis of collective choice, political processes, and group decision making.

234A • Financial Management (4) Woodward
Managerial aspects of selection of assets to acquire methods by which they are financed and policies for disbursement or reinvestment of the earnings from these assets. Emphasis on market forces which produce prices that allow managers to make these decisions.

234B • Financial Management (4) Woodward
Develops a general theory of capital asset prices, then examines the array of financial assets within this framework. With this basis, the course covers the principles of portfolio construction and portfolio evaluation.

235A-B • Money and Banking (4-4) Pippenger, LeRoy
Prerequisites: Econ 204A.
A: Monetary theory.
B: Topics in monetary analysis—may include advanced study of monetary equilibrium, problems of monetary control, the efficient capital markets model, and rational expectations.

240 • Mathematics for Economists (4) Staff
Selected topics in mathematics of particular importance to economists including the calculus, difference and differential equations.

244A-B • Mathematical Economics (4-4) Miyao, Sengupta
Mathematical analysis of economic theory.

245A-B • Econometrics (4-4) Cooley, Phillips, Sengupta
A: Development of the theory of single equation and simultaneous equations estimation. **B:** Econometric studies, spectral analysis, multivariate techniques.

246 • Business Forecasting (4) Cooley, Krouse
Prerequisites: Econ 140 or Econ 141C.
Various methods for econometric forecasting including statistical decision theory, Box-Jenkins, adaptive models, single and simultaneous structural equation models, and input-output analysis. Applications of various techniques to forecasting needs of management, such as sales and inventory, will be discussed.

250A—B • Labor Economics (4-4) Phillips, Staff
Theoretical and empirical analyses of the structure of wages, the labor market, distributive shares in national income, investment in human resources, national manpower and wage policy and other topics in industrial relations.

260A • Natural Resources (4) Deacon
Capital theory and welfare economics applied to natural resource industries, the role of renewable and nonrenewable resources in the process of economic growth, analysis of externalities and common property resources, public investment criteria.

260B • Natural Resources (4) Mead
Capital theory, welfare economics and benefit cost analysis at theoretical and applied levels, as they relate to energy resource management and public policy.

270 • The Management of Organizations (4) Alexander
Management functions in the context of organization theory. Course studies formal organizations from the classical, systems and behavioral science points of view and such major management functions as planning, decision making,

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*See N2 for 198/199 independent studies unit limitations.

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controlling and communicating. Not offered 1979-80.

280A-B • International Trade (4-4) Marshall, Pippenger, Votey.
Prerequisite: Econ 204A.
A: International trade theory. **B:** International finance.

594AA—594ZZ • Special Topics in Economics (1-4) Staff.
Prerequisites: Graduate standing and consent of instructor.
Special seminar on research subjects of current interest.

595AA—595ZZ • Group Studies in Economics (4) Staff.
Prerequisites: Graduate standing and consent of instructor.
Critical review of research in selected fields.

596AA—596ZZ • Directed Reading and Research (2-4) Staff.
Prerequisites: Graduate standing and consent of instructor.
Individual tutorial.

597 • Individual Study for Master's Comprehensive Examination and Ph.D. Examinations (1-12) Staff.
Prerequisites: Graduate standing and consent of instructor.
No unit credit allowed toward advanced degree.

598AA—598ZZ • Master's Thesis Research and Preparation (1-12) Staff.
Prerequisites: Graduate standing and consent of instructor.
Only for research underlying the thesis, writing the thesis. No unit credit toward the degree will be given.

599AA—599ZZ • Dissertation and Preparation (1-12) Staff.
Prerequisites: Graduate standing and consent of instructor.
Only for preparation of the dissertation.

1. University of California, S. B., Perry Shapiro, 73-10322 + eight reports.

2. 13 more reports from above award.

3. Three reports from above. (Put here for reasons of space.)

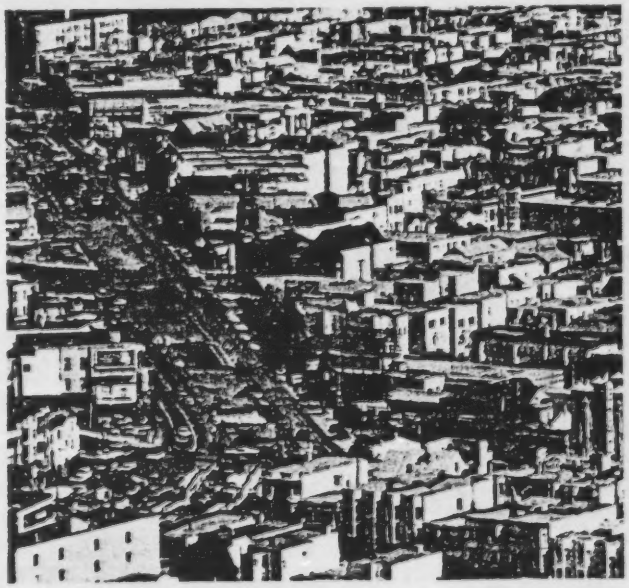
UCSB PROGRAM IN URBAN ECONOMICS

THE CHALLENGE
Urban Crisis

Crisis conditions are predicted or already exist for virtually all the urban public services: *water, energy, waste disposal, transportation, health services, public safety* and *criminal justice*. At the same time there has been relatively little effort by colleges and universities to specifically train people for leadership roles at the local and regional level where these crises occur. A major facet of the challenge is to create an effective program to prepare highly motivated individuals with the competence to deal with these burgeoning public services and environmental problems plaguing local governments.

UCSB's ANSWER:
Urban Economics

The Urban Economics option in the Masters Degree program is unique in its approach to this challenge. It is problem oriented and highly flexible. The working philosophy of the program is to view the urban problem as one of resource allocation. The core of classroom study will be courses in economic decision-making. Economics, by its very nature, unites the behavioral relationships of the social sciences with the technical realities of the hard sciences, taking into account the resource constraints faced by society. Although the content of courses in the program will evolve as problems evolve, it is expected that economics will continue to play a pivotal role in the program as it evolves. Economic theory courses will comprise the first of the four subgroups in the curriculum.



The second subgroup will deal with the analysis and implementation of public policy. Courses in both economics and political science are included in this set. These courses are designed to acquaint the student with the realities under which decisions are formulated. Both course requirements and course content in this set will be subject to change as needs evolve.

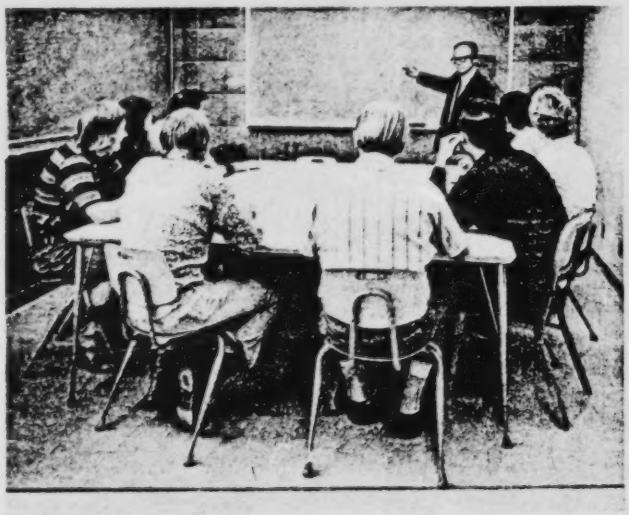
The third set deals with tools, such as statistics and accounting, that will be useful to the student in his future employment. Additionally the student will be required to participate in a laboratory designed to provide him the opportunity to practice newly acquired skills and to learn the techniques of modern computerized data manipulation and computation.

The fourth group of courses will accommodate the individual student's area of particular interest in the urban sector. These will be elective and will relate to such areas as urban and regional economics; environmental economics; economics of human resources relating to education, public health, criminal justice, and manpower problems; public finance; public administration; urban politics; and appropriate courses in sociology, biology, physics and various areas of specialization in engineering relating to the provision of urban services and the control of the urban environment.

The final requirement for the degree will be a masters project: a report on research, initiated by the student and dealing with a problem relevant to his internship. An example of an appropriate project is the initiation of an input-output study of the community in which the student is interned.

Students entering this 18 months program with established competence in some requirements of the program will be provided a curriculum tailored to their particular needs and interests. The student begins his course of study in the Fall and his first nine months are spent in the classroom-related activities described below. In June the student begins a six month internship with a local public agency for the purpose of focusing his academically acquired skills on job experiences.

During the six months in the field with other interns in his area, the student will attend bi-weekly seminars, led by a faculty participant in the program. The seminar, conducted at locations convenient to the students work place, will allow interns to share their work experiences and to receive advice on work-related problems. At the completion of the six month internship the student will return to campus to complete his course requirements.



THE UCSB CAMPUS

The University of California at Santa Barbara is located in one of the more rapidly growing regions of the United States. The location is a microcosm of the Southern California region. There are forces for rapid expansion and there are voices raised against expansion in any form. Some kind of urban change is inevitable. Here is an opportunity to take advantage of lessons learned in the development of similar regions.

Academic training will be centered in the Department of Economics with support from the Department of Political Science and from the UCSB Computer Center. Campuswide facilities provide a wide variety of support for special interests and the research needs of students in the program.

PART III

Section f

VIDEOTAPED INSTRUCTIONAL MATERIALS

This section contains a list of titles of videotaped instructional materials, keyed lecture notes, problem sets and lecture abstracts prepared by the Urban Economics Program.

THE UCSB VIDEOTAPE LECTURE SERIES

ON URBAN ECONOMIC ANALYSIS

The enclosed videotapes were produced cooperatively by the Urban Economics Program and the Learning Resources Center at the University of California, Santa Barbara. Our aim in producing these instructional materials was both to allow students (particularly those enrolled in part-time study programs) access to key instructional materials at times and places best suited to their particular circumstances, and to allow instructors to substitute or supplement classroom lectures with media based instructional tools. Enclosed are: a list of the contents of the videotape library (including names of instructors, tape module titles and running times); a set of abstracts for individual tapes in the library; sets of prepared notes, diagrams, and problem sets for the more analytical lecture series.

URBAN ECONOMICS PROGRAM
VIDEOTAPE LIBRARY

November 13, 1978

ECONOMICS	NO.	TITLE	TIME	TAPE STOCK USED	RECORDED
V. Agarwal:					
Master	C-845	Intro to Input/Output Analysis	37:45	UCA 40	9/13/78
Circulation	C-846	" " " "		"	
Master	C-849	Input/Output Modeling	34:20	"	9/14/78
Circulation	C-850	" " "		"	
Master	C-851	Input/Output Modeling cont..	39:17	"	9/14/78
Circulation	C-852	" " " "		"	
Master	C-855	Input/Output Multipliers	48:28	UCA 40	9/20/78
Circulation	C-856	" " "		"	
Master	C-919	Regional & Interregional Input-	33:00	UCA 40	11/8/78
Circulation	C-920	Output Theory		"	
T. Anagnoson :					
Master	C-823	Synoptic Decision Making	36:49	UCA 40	9/5/78
Circulation	C-822	" " "		"	
Master	C-826	Political Decision Making	40:37	"	9/6/78
Circulation	C-827	" " "		"	
J. Sonstilie:					
Master	C-836	Willingness to Pay for Private Goods	55:50	UCA 40	9/12/78
Circulation	C-837	" " " " "		"	
Master	C-860	Evaluating Public Projects	39:05	"	9/25/78
Circulation	C-861	" " "		"	
Master	C-864	Consumer Surplus	35:41	"	9/27/78
Circulation	C-865			"	
Master	C-872	Discounting Future Benefits & Costs	43:10	"	9/29/78
Circulation	C-873	" " " "		"	

ECONOMICS cont....

	NO.	TITLE	TIME	TAPE STOCK USED	RECORDED
W. Comanor					
Master	C-713	Intro to Theory of Choice	29:44	UCA 40	6/5/78
Circulation	C-930			"	
Master	C-804	Indifference Curves & Demand Curves	37:00	UCA 40	8/28/78
Circulation	C-803	" " " "		"	
Master	C-729	Into to Demand Analysis	36:13	"	6/22/78
Circulation	C-730	" " "		"	
Master	C-785	Marginal Utility of Income	29:06	"	8/8/78
Circulation	C-810	" " "		"	
Master	C-746	Consumer Surplus	37:11	"	7/10/78
Circulation	C-747	" "		"	
Master	C-774	Theory of Exchange	37:18	"	7/31/78
Circulation	C-775	" " "		"	
Master	C-777	Intro to Theory of the Firm	32:08	"	8/8/78
Circulation	C-778	" " " "		"	
Master	C-779	Production Functions & the Demand for Inputs	27:33	"	8/9/78
Circulation	C-780	" " " "		"	
Master	C-781	Principles of Efficient Pricing	34:31	"	8/8/78
Circulation	C-782	" " " "		"	
P. Shapiro:					
Master	C-771	Mathematical Programming # 1	33:40	"	7/19/78
Circulation	C-772	" " "		"	
Master	C-769	Mathematical Programming # 2	35:33	UCA 60	7/1978
Circulation	C-770	" "		"	
Master	C-900	Mathematical Programming # 3	28:50	UCA 40	10/23/78
Circulation	C-899	" " "		"	
Master	C-905	Mathematical Programming # 4	37:55	"	10/27/78
Circulation	C-904	" " "		"	
Master	C-906	Mathematical Programming # 5	38:30	"	10/30/78
Circulation	C-907	" " "		"	
Master	C-911	Mathematical Programming # 6	32:25	"	11/1/78
Circulation	C-910	" " "		"	
Master	C-915	Mathematical Programming # 7	20:52	"	11/8/78
Circulation	C-914	" " "		"	

27 Lectures

Total 38 40's
16 60's

URBAN AND REGIONAL MODELING

Lecture Notes for Professor Agarwal's

Videotapes

Input - Output Table

↓

Input - Output Model

↓

Multiplier analysis

↓

Regional I/O Model

↓

Inter regional I/O Model

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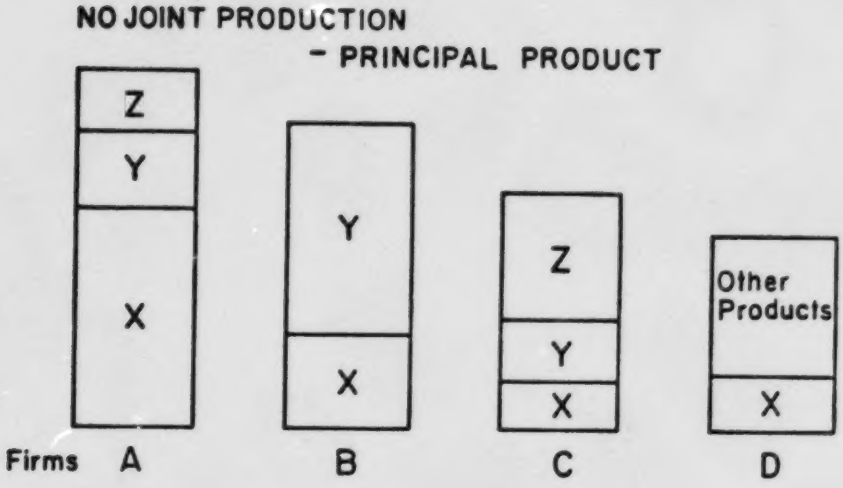
Applications

	IND A	IND B	IND C	House-hold	Govt.	Gross Output
IND A	3	5	5	4	3	20
IND B	5	6	10	3	1	25
IND C	7	5	1	7	0	20
House-hold	1	3	3	0	1	8
Govt.	4	6	1	0	0	11
Gross Outlay	20	25	20	14	5	84

Assumptions

1) No Capacity Constraints.
2) No Externalities.
3) System is at equalibrium at given prices.
4) No Joint Production.
5) Constant Returns to Scale.
6) Fixed Coefficients of production.



Constant Returns to Scale.

if $Q = f(K,L)$.

then

$$f(\lambda K, \lambda L) = \lambda f(K,L).$$
$$= \lambda Q.$$

Example

$$Q = AL^{a}K^{1-a}$$

then $A(\lambda L)^{a}(\lambda K)^{1-a}$

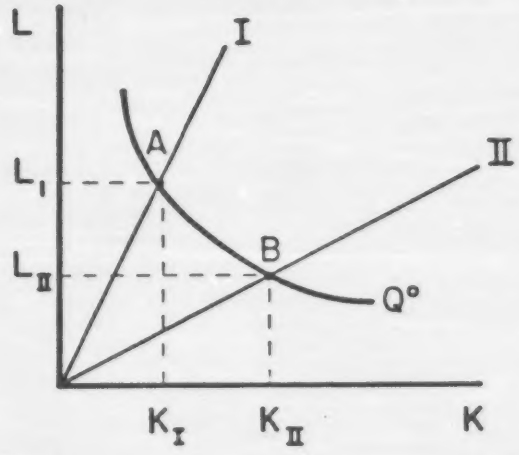
$= A\,\lambda^{a}L^{a}\,\lambda^{1-a}K^{1-a}$

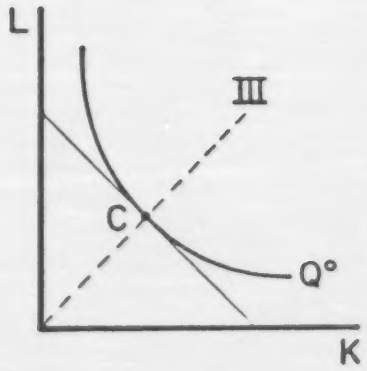
$= \lambda^{a}\lambda^{1-a}AL^{a}K^{1-a}$

$= \lambda\, AL^{a}K^{1-a}$

$= \lambda Q$

Fixed Coefficients of Production





X_{11}	X_{12}	X_{13}	Y_{14}	Y_{15}	X_1
X_{21}	X_{22}	X_{23}	Y_{24}	Y_{25}	X_2
X_{31}	X_{32}	X_{33}	Y_{34}	Y_{35}	X_3
V_{41}	V_{42}	V_{43}	V_{44}	V_{45}	V_4
V_{51}	V_{52}	V_{53}	V_{54}	V_{55}	V_5
X_1	X_2	X_3	Y_4	Y_5	X

X_{11}	X_{12}	X_{13}	Y_1	X_1
X_{21}	X_{22}	X_{23}	Y_2	X_2
X_{31}	X_{32}	X_{33}	Y_3	X_3
V_1	V_2	V_3	V_4	V
X_1	X_2	X_3	Y_4	X

$\frac{x_{11}}{x_1} = a_{11}$	$\frac{x_{12}}{x_2} = a_{12}$	$\frac{x_{13}}{x_3} = a_{13}$
$\frac{x_{21}}{x_1} = a_{21}$	$\frac{x_{22}}{x_2} = a_{22}$	$\frac{x_{23}}{x_3} = a_{23}$
$\frac{x_{31}}{x_1} = a_{31}$	$\frac{x_{32}}{x_2} = a_{32}$	$\frac{x_{33}}{x_3} = a_{33}$

$= [A]$

$$a_{ij} = x_{ij} / x_j$$

STABILITY CONDITIONS

1) $\sum_{j=1}^{n} a_{ij} \leq 1$ and for at least one j $\sum_{j=1}^{n} a_{ij} < 1$

2) $\nexists$ j such that $\sum_{j=1}^{n} a_{ij} > 1$

ERROR

replace $\sum_{j=1}^{n}$ by $\sum_{i=1}^{n}$

$x_{11} = a_{11} x_1$	$x_{12} = a_{12} x_2$	$x_{13} = a_{13} x_3$	Y_1	X_1
$x_{21} = a_{21} x_1$	$x_{22} = a_{22} x_2$	$x_{23} = a_{23} x_3$	Y_2	X_2
$x_{31} = a_{31} x_1$	$x_{32} = a_{32} x_2$	$x_{33} = a_{33} x_3$	Y_3	X_3

$a_{11}x_1$	$a_{12}x_2$	$a_{13}x_3$	Y_1	X_1
$a_{21}x_1$	$a_{22}x_2$	$a_{23}x_3$	Y_2	X_2
$a_{31}x_1$	$a_{32}x_2$	$a_{33}x_3$	Y_3	X_3

$$x_1 = a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + Y_1$$

$$x_2 = a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + Y_2$$

$$x_3 = a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + Y_3$$

OR

$$x_1 - a_{11}x_1 - a_{12}x_2 - a_{13}x_3 = Y_1$$

$$x_2 - a_{21}x_1 - a_{22}x_2 - a_{23}x_3 = Y_2$$

$$x_3 - a_{31}x_1 - a_{32}x_2 - a_{33}x_3 = Y_3$$

OR

$$\begin{aligned} x_1 - a_{11}x_1 \quad &- a_{12}x_2 \quad - a_{13}x_3 = Y_1 \\ - a_{21}x_1 + x_2 &- a_{22}x_2 \quad - a_{23}x_3 = Y_2 \\ - a_{31}x_1 \quad &- a_{32}x_2 + x_3 - a_{33}x_3 = Y_3 \end{aligned}$$

OR

$$\begin{aligned} (1 - a_{11})x_1 \quad &- a_{12}x_2 \quad - a_{13}x_3 = Y_1 \\ - a_{21}x_1 + (1 - a_{22})x_2 \quad &- a_{23}x_3 = Y_2 \\ - a_{31}x_1 \quad &- a_{32}x_2 + (1 - a_{33})x_3 = Y_3 \end{aligned}$$

$$\begin{bmatrix} 1-a_{11} & -a_{12} & -a_{13} \\ -a_{21} & 1-a_{22} & -a_{23} \\ -a_{31} & -a_{32} & -a_{33} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix}$$

OR

$$[I - A]\,[X] = [Y]$$

Where I is an Identity Matrix and

A is the direct Coefficient Matrix

$$[I - A]\,[X] = [Y]$$

OR

$$[I - A]^{-1}\,[I - A]\,[X] = [I - A]^{-1}[Y]$$

OR

$$[\,I\,]\,[X] = [I - A]^{-1}[Y]$$

OR

$$[X] = [I - A]^{-1}[Y]$$

Let us denote $[I - A]^{-1}$ as matrix $[E]$

Hawkins - Simon Stability Condition:

There can be no negative entry in the table of direct and indirect requirements.

In Summary, I O analysis describes 3 elements

a) Final demands.

b) Input requirements of each sector

c) Gross Output of each industry.

$$[X] = [I - A]^{-1}[Y]$$

Let us denote $[I - A]^{-1}$ as matrix $[E]$

Hawkins - Simon Stability Condition:

There can be no negative entry in the table of direct and indirect requirements.

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} E_{11} & E_{12} & E_{13} \\ E_{21} & E_{22} & E_{23} \\ E_{31} & E_{32} & E_{33} \end{bmatrix} \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix}$$

If $\begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$ then $\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} \quad \\ \quad \\ \quad \end{bmatrix}$

If $\begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$ then $\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} \quad \\ \quad \\ \quad \end{bmatrix}$

$$\begin{bmatrix} \frac{x_{11}}{x_1} = a_{11} & \frac{x_{12}}{x_2} = a_{12} & \frac{x_{13}}{x_3} = a_{13} \\ \frac{x_{21}}{x_1} = a_{21} & \frac{x_{22}}{x_2} = a_{22} & \frac{x_{23}}{x_3} = a_{23} \\ \frac{x_{31}}{x_1} = a_{31} & \frac{x_{32}}{x_2} = a_{32} & \frac{x_{33}}{x_3} = a_{33} \end{bmatrix} = [A]$$

$$a_{ij} = x_{ij} / x_j$$

X_{11}	X_{12}	X_{13}	Y_1	X_1
X_{21}	X_{22}	X_{23}	Y_2	X_2
X_{31}	X_{32}	X_{33}	Y_3	X_3
V_1	V_2	V_3		X

a_{11}	a_{12}	a_{13}
a_{21}	a_{22}	a_{23}
a_{31}	a_{32}	a_{33}
l_1	l_2	l_3

$$P_1 \geq P_1 a_{11} + P_2 a_{21} + P_3 a_{31} + P_L l_1$$

$$P_2 \geq P_1 a_{12} + P_2 a_{22} + P_3 a_{32} + P_L l_2$$

$$P_3 \geq P_1 a_{13} + P_2 a_{23} + P_3 a_{33} + P_L l_3$$

$$P_1 = P_1 a_{11} + P_2 a_{21} + P_3 a_{31} + P_L I_1$$

$$P_2 = P_1 a_{12} + P_2 a_{22} + P_3 a_{32} + P_L I_2$$

$$P_3 = P_1 a_{13} + P_2 a_{23} + P_3 a_{33} + P_L I_3$$

OR

$$\begin{bmatrix} P_1 \\ P_2 \\ P_3 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{21} & a_{31} \\ a_{12} & a_{22} & a_{32} \\ a_{13} & a_{23} & a_{33} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \\ P_3 \end{bmatrix} + P_L \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

OR

$$[P] = [A'][P] + P_L [L]$$

OR

$$[I][P] = [A'][P] + P_L [L]$$

OR

$$[I][P] - [A'][P] = P_L [L]$$

OR

$$[I - A'][P] = P_L [L]$$

OR

$$[I - A']^{-1}[I - A'][P] = [I - A']^{-1} P_L [L]$$

OR

$$[P] = [I - A']^{-1} P_L [L]$$

	IND 1	IND 2	House hold	Other Demand	Gross Output
IND 1	20	45	30	5	100
IND 2	40	15	30	65	150
House hold	20	60	10	10	100
Other Payments	20	30	30	—	80
Gross Outlay	100	150	100	80	430

Coefficient Matrix

$$A = \begin{bmatrix} 20/100 & 45/150 \\ 40/100 & 15/150 \end{bmatrix}$$

$$\text{labor} \quad \begin{matrix} 20/100 & 60/150 \end{matrix}$$

OR

$$A = \begin{bmatrix} .20 & .30 \\ .40 & .10 \end{bmatrix}$$

$$\text{labor} \quad \begin{matrix} .20 & .40 \end{matrix}$$

$$[I - A]^{-1} = \begin{bmatrix} 1{\cdot}50 & 0{\cdot}50 \\ 0{\cdot}67 & 1{\cdot}33 \end{bmatrix} = E$$

Implications:

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 1{\cdot}50 & 0{\cdot}50 \\ 0{\cdot}67 & 1{\cdot}33 \end{bmatrix} \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix}$$

OUTPUT OR COLUMN MULTIPLIER:

This multiplier measures the sum of all direct and indirect requirements, from all sectors, needed to meet one unit of demand for a given industry's output.

Given final demand of $\begin{bmatrix} 1 \\ 0 \end{bmatrix}$

Output Requirements are.

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 1{\cdot}50 \\ 0{\cdot}67 \end{bmatrix}$$

If final demand is $\begin{bmatrix} 0 \\ 1 \end{bmatrix}$

then Output Requirements are

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0{\cdot}50 \\ 1{\cdot}33 \end{bmatrix}$$

Let V_i denote the value added per unit of output of sector i. Then in our example

$$V_1 = \cdot 20$$

$$V_2 = \cdot 40$$

Direct and Indirect value added for sector 1

$$= (1\cdot 50)(\cdot 20) + (0\cdot 67)(\cdot 40)$$

$$= \cdot 300 + \cdot 268$$

$$= \cdot 568$$

Similarly for sector 2

Value added

$$= (0\cdot 50)(\cdot 20) + (1\cdot 33)(\cdot 40)$$

$$= \cdot 100 + \cdot 532$$

$$= \cdot 632$$

INCOME MULTIPLIER OR SIMPLE MULTIPLIER (TYPE I)

= Ratio of (direct and indirect) income change to the direct change in income resulting from a unit increase in final demand.

$$MS_j = \frac{\sum_{i=1}^{n} v_i e_{ij}}{v_j} \text{ for Sector } j$$

In Our Example

$$MS_1 = \frac{\cdot 568}{\cdot 2} = 2\cdot 84$$

$$MS_2 = \frac{\cdot 632}{\cdot 4} = 1\cdot 58$$

OVERALL INCOME EFFECT

= Direct Effect + Indirect Effect + Induced Effect

	IND 1	IND 2	House hold	Other Demand	Gross Output
IND 1	20	45	30	5	100
IND 2	40	15	30	65	150
House hold	20	60	10	10	100
Other Payments	20	30	30	—	80
Gross Outlay	100	150	100	80	430

Coefficient Matrix

$$B = \begin{bmatrix} 20/100 & 45/150 & 30/100 \\ 40/100 & 15/150 & 30/100 \\ 20/100 & 60/150 & 10/100 \end{bmatrix}$$

Or

$$B = \begin{bmatrix} .2 & .3 & .3 \\ .4 & .1 & .3 \\ .2 & .4 & .1 \end{bmatrix}$$

$$[I-B]^{-1} = H = \begin{bmatrix} 2{\cdot}09 & 1{\cdot}18 & 1{\cdot}09 \\ 1{\cdot}27 & 2{\cdot}00 & 1{\cdot}09 \\ 1{\cdot}03 & 1{\cdot}15 & 1{\cdot}82 \end{bmatrix}$$

$$\text{if } y = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

$$\text{then} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 2{\cdot}09 \\ 1{\cdot}27 \\ 1{\cdot}03 \end{bmatrix}$$

FULL MULTIPLIER or INCOME MULTIPLIER TYPE II:

= Ratio of overall income change to direct income change due to a unit increase in demand for a given sector.

For Sec. 1

$$MF_1 = \frac{1{\cdot}03}{{\cdot}2} = 5{\cdot}15$$

For Sec. 2

$$MF_2 = \frac{1{\cdot}15}{{\cdot}4} = 2{\cdot}875$$

1) Structure of an I-O Table.

   a) Processing Sector.
   b) Final Demand Sector.
   c) Final Payment Sector.

2) Constructing I-O Models

   a) Assumptions.
   b) Direct Coefficient Matrix.
   c) Direct & Indirect Coefficient Matrix.

3) Conversion of an I-O Table given in physical units into monetary units.

4) Multiplier Analysis and I-O Models.
   a) Simple Income Multipliers. (MS).
   b) Full Income Multipliers. (MF).

Consistent Forecasting: Given the projections of final demand, the output requirements of each industry are consistent with the demands for both final and intermediate goods.

STEPS involved in Forecasting.

a) Obtain projections for every final demand sector.
b) Collapse all final demand sectors into one sector.
c) Calculate Direct Coefficient Matrix.
d) Derive Direct & Indirect Requirement Matrix.
e) Obtain Gross Output Requirements for projected Final Demand.

f) Update entries for Processing Sector as well as Final Payment Sector.

g) Also show demands for each and every final demand sector.

h) Thus obtain new I-O Table.

Regional Input Output Models.

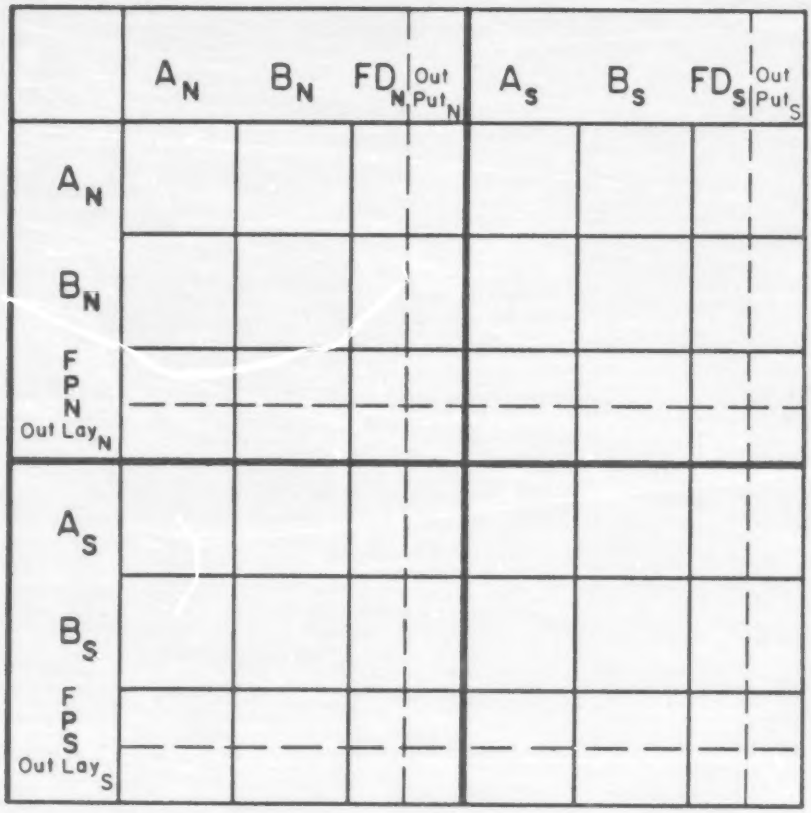
(Two Types)

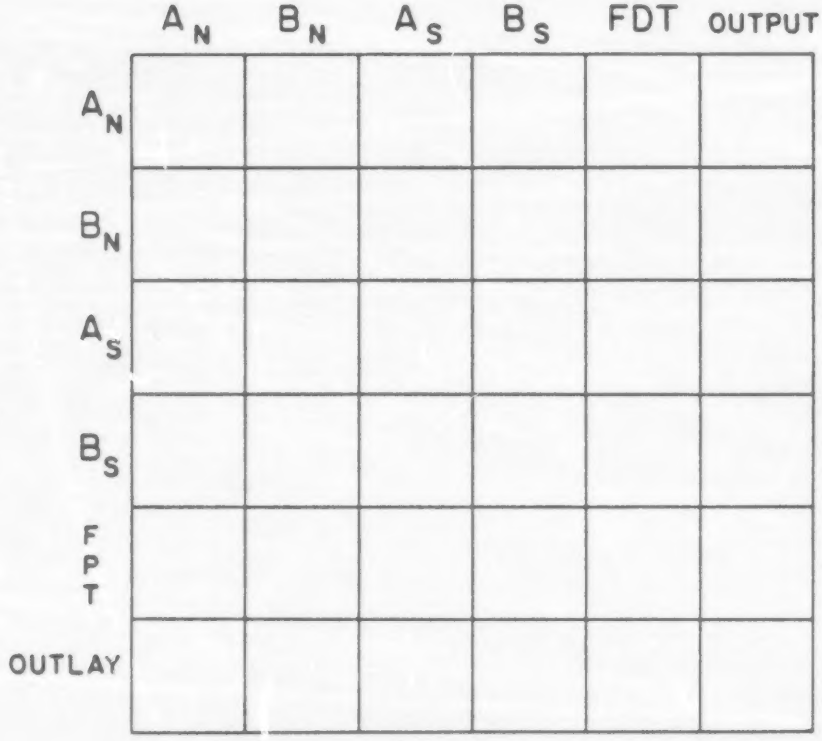
1. Square Type.
2. Dog - Leg Type.

PROCESSING SECTOR	LOCAL FINAL DEMAND	EXPORT MATRIX	GROSS OUTPUT
LOCAL FINAL PAYMENTS			
IMPORT MATRIX			
GROSS OUTLAY			

INTER-REGIONAL MODELS

1. Balanced Regional Models.
2. Pure Interregional Models.





INTERAREAL INPUT COEFFICIENTS

Example

Chenry, Clark and Cao-Pinna
study of Italy.

North - developed

South - backward

Investigated the effect of development programs in Southern Italy.

Findings

150 billion liras - invested in South generates

Income	South	North
Direct	63 billion	0
Indirect	131 billion	160 billion

POLITICAL DECISIONMAKING

Lecture Notes for Professor Anagnason's

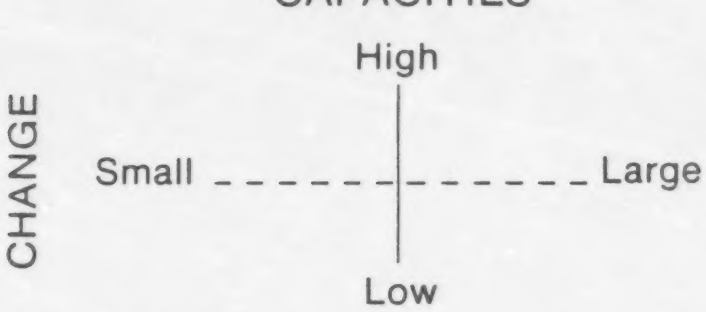
Videotapes

SYNOPTIC MODEL

a. problem formulation
b. goal specification
c. resource combinations
d. inputs/outputs/outcomes
e. decision criterion

INCREMENTAL MODEL

a. informal
b. inability to maximize
c. bargaining and voting



A. FORMULATE THE PROBLEM

— political problems
— cause/effect problems

B. LIST ALL RESOURCES

– price them

C. LIST COMBINATIONS

– price them
– difficulty varies by area

RESOURCES FOR POVERTY PLANNING:

– Family sources
– Food stamps
– Welfare/SS/SSI
– Medicaid/Housing

E. DECISION CRITERIA

– efficiency
– political feasibility
– equity
– maximax
– maximin
– something else
– 2+ of the above

ASSUMPTIONS (synoptic)

– specific goals
– common measurement unit
– information capacity

SATISFICING
(satisfying and sufficing)

Achieving a goal noticibly
short of the maximum goal

BENEFITS OF INCREMENTALISM

- focus on known experience
- reduced number of alternatives
- less complexity

ASSUMPTIONS
(political decisionmaking)

- information
- uncertainty

DISTRIBUTIVE POLICY

- particularized benefits
- local initiative
- vote trading
  (reciprocity norm)
- fairness or equity in
  project distribution

REDISTRIBUTIVE POLICY

- open and large redistributions of income
- political conflict (clashes among classes)
- public clearly perceives issues

REGULATORY POLICY

- specification of good behavior
- interest group conflict
- identifiable winners
- little public perception

	WORST	BEST
I-2	1	2
III-1	3	4

CALIFORNIA WATER

- a redistributive problem
- cheap water/large quantities
- environmental/no growth

BENEFIT COST ANALYSIS

Abstracts for Professor Sonstelie's

Videotapes

Willingness to Pay for Private Goods

The first lecture is concerned with establishing a criteria for evaluating public projects. The imcompleteness of the Pareto ranking is demonstrated, and the compensation principle is offered as a way of making that ranking complete. It is shown that the compensation principle may lead to an incomplete ranking, however, and other possible criterion are considered.

Evaluating Public Projects

In the second lecture, the problem of estimating willingness to pay for market goods is taken up. It is shown that the market price of such a good is a measure of the marginal willingness to pay for that good and that that price can be used to calculate a first-order approximation to the willingness to pay for a discrete change in the amount of a good provided. This first-order approximation is shown to be equivalent to a measure of the change in national income resulting from the project. It is demonstrated that an increase in national income is a necessary but not a sufficient condition for an increase in social welfare. The issue of secondary benefits and costs is also addressed.

Consumer Surplus

In the third lecture, the concept of consumer surplus is introduced as an exact measure of willingness to pay. The relationship between consumer surplus and national income as measures of welfare is discussed. The problem of estimating the benefits and costs of nonmarket goods is also taken up, and the travel-cost method of estimating the benefits of recreation areas is demonstrated.

Discounting Future Benefits & Costs

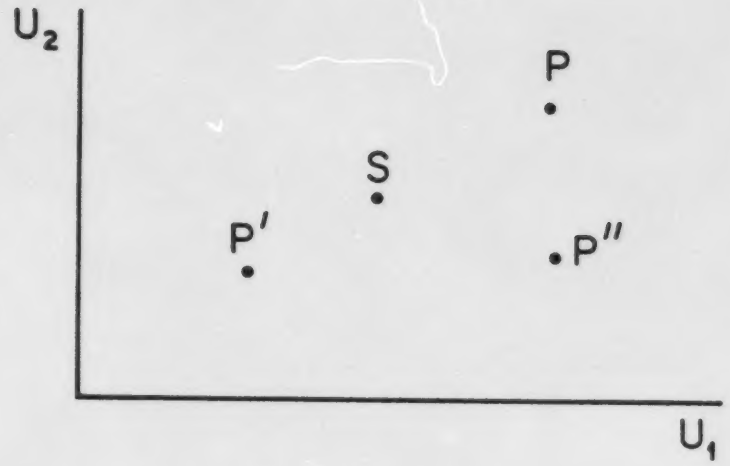
The final lecture deals with the discounting of costs and benefits that are expected to occur in the future. Two alternatives for determining the

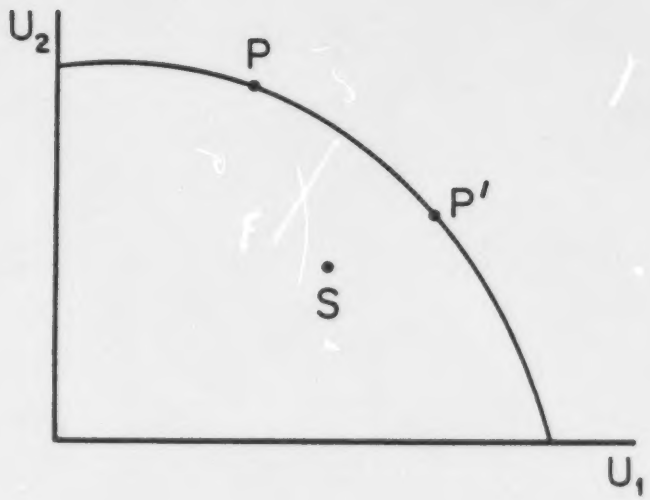
proper discount rate are considered--the opportunity cost approach and the rate of time preference approach. Because of the tax on capital income, the proper rate is a weighted average of the two rates. The treatment of risk in discounting future benefits and costs is also discussed.

BENEFIT COST ANALYSIS

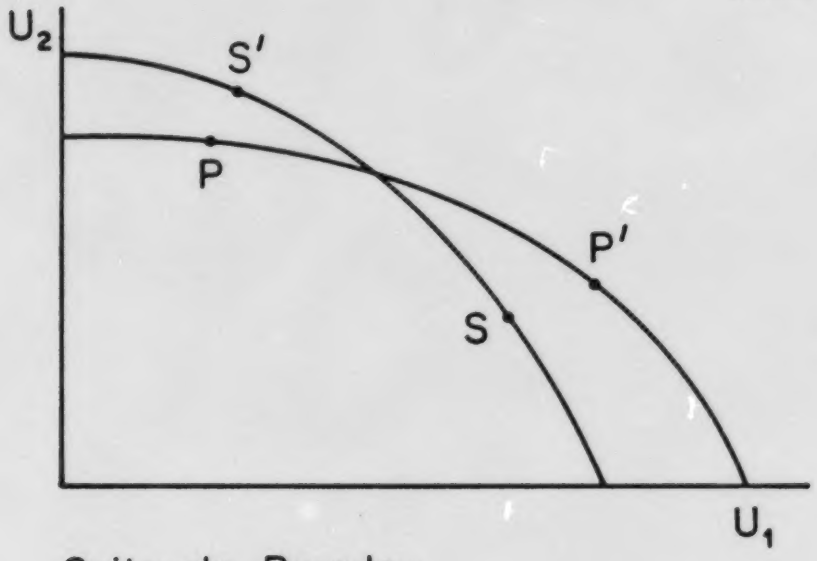
Lecture Notes for Professor Sonstelie's

videotapes





$$\text{NET BENEFIT} = \sum_i \text{WTP}_i$$



Scitovsky Paradox

$$\sum_j w_j \cdot WTP_j$$

$(x_1^\circ, \ldots, x_n^\circ)$; $(x_1', \ldots, x_n')$

$U(x_1, \ldots x_n)$

$\Delta U \equiv U(x_1', \ldots, x_n') - U(x_1^\circ, \ldots, x_n^\circ)$

$$\Delta U \approx \sum_i \frac{\partial U}{\partial x_i}(x_i' - x_i^\circ)$$

$$\frac{\partial U}{\partial x_i} = \lambda p_i$$

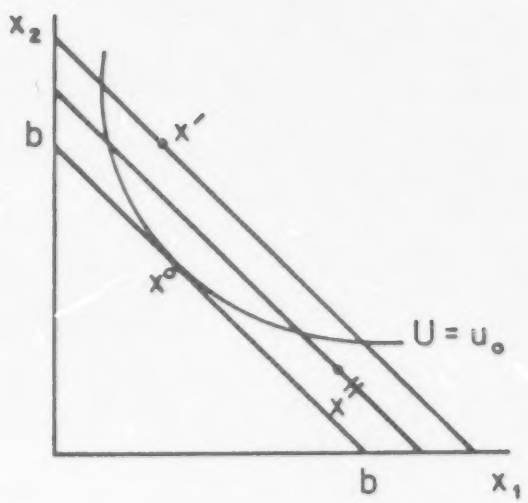
$$\Delta U \approx \sum_i \lambda p_i (x_i' - x_i^\circ)$$

$$\frac{\Delta U}{\lambda} \approx \sum_i p_i (x_i' - x_i^\circ)$$

$$WTP \approx \sum_i p_i (x_i' - x_i^\circ)$$

$$\sum_j WTP_j \approx \sum_j \sum_i p_i (x_{ij}' - x_{ij}^\circ)$$

$$\sum_j WTP_j \approx \sum_i p_i (X_i' - X_i^\circ)$$



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$(X_1^\circ, \ldots, X_n^\circ)$ before project

$(X_1', \ldots, X_n')$ after project

$(\Delta X_1', \ldots, \Delta X_n')$ net effect of project
where $\Delta X_i' = X_i' - X_i^\circ$

$(\Delta X_1^p, \ldots, \Delta X_n^p)$ Primary Effect

$(\Delta X_1^s, \ldots, \Delta X_n^s)$ Secondary Effects
where $\Delta X_i^s = \Delta X_i' - \Delta X_i^p$

$\sum_i C_i X_i = Y$ Transformation Constraint

$\sum_i C_i \Delta X_i = 0$

$\sum_i C_i \Delta X_i^s = 0$

$$\sum_i p_i \Delta X_i = \sum_i p_i \Delta X_i^p + \sum p_i \Delta X_i^s$$

$$= \sum_i p_i \Delta X_i^p + \sum_i p_i \Delta X_i^s - \sum C_i \Delta X_i^s$$

$$= \underbrace{\sum_i p_i \Delta X_i^p}_{\text{PRIMARY BENEFITS}} + \underbrace{\sum_i (p_i - C_i) \Delta X_i^s}_{\text{SECONDARY BENEFITS}}$$

$$WTP = \left(\frac{1}{\lambda}\right) dU$$

first order approximation

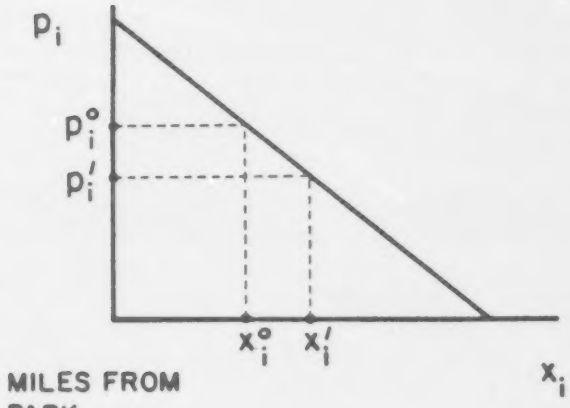
$$WTP \approx \frac{1}{\lambda} \frac{\partial U_i}{\partial x_i} \left(x_i' - x_i^\circ\right)$$

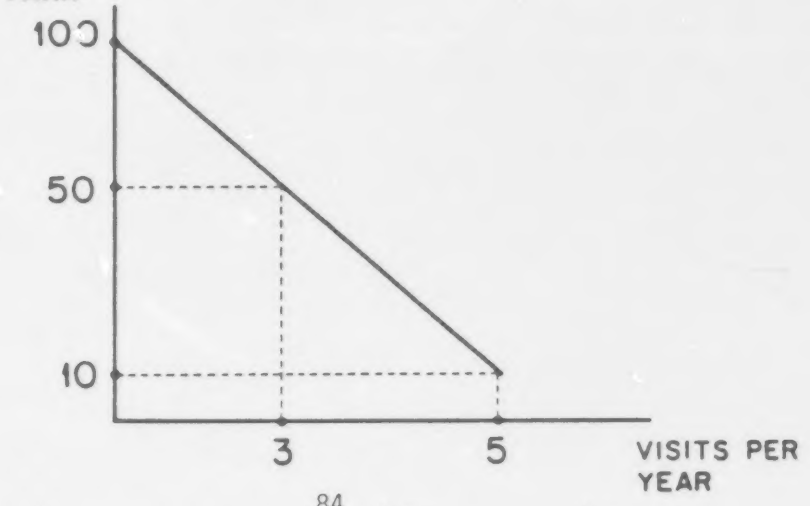
$$WTP \approx p_i^\circ (x_i' - x_i^\circ)$$

Exact Expression

$$WTP = \int_{x_i^\circ}^{x_i'} \left(\frac{1}{\lambda}\right)\left(\frac{\partial U}{\partial x_i}\right) dx_i$$

$$= \int_{x_i^\circ}^{x_i'} p_i \, dx_i$$





K ; Capital Costs

$B_1, B_2, \ldots, B_i, \ldots$; Future Benefits

$P_1, P_2, \ldots, P_i, \ldots$; Prices for Future Consumption

$\sum_i P_i B_i$; Present Value

$(1+r_c)$; one year

$(1+r_c)^2$; two years

$(1+r_c)^i$; i years

$P_i = \frac{1}{(1+r_c)^i}$

$$PV_c = \sum \frac{B_i}{(1+r_c)^i}$$

$PV_c > K$; Benefits exceeds Costs

$(1+r_p)^i$; return after i years

$\frac{B_i}{(1+r_p)^i}$; investment required now

$$PV_p = \sum_i \frac{B_i}{(1+r_p)^i}$$

$PV_p > K$; public investment best

K ; capital cost

$r_g K$; return per year

$K = \Delta I + \Delta C$

$r_g K - r_p \Delta I$; net consumption benefit

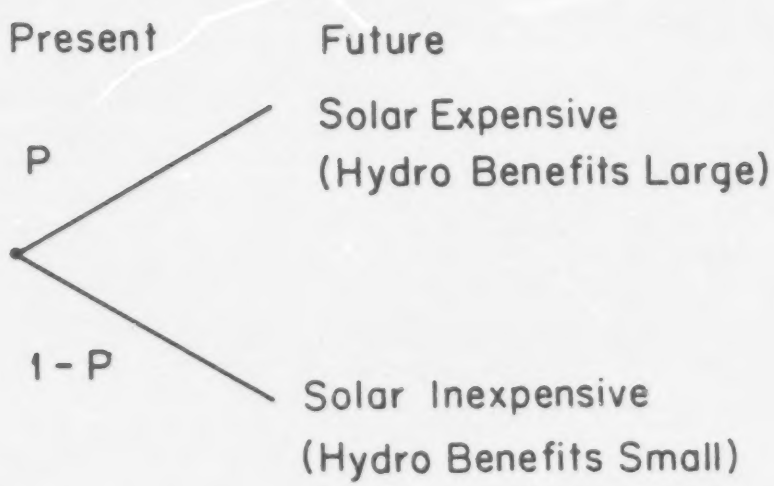
$$PV = \sum \frac{r_g K - r_p \Delta I}{(1+r_c)^i}$$

$$PV = \frac{r_g K - r_p \Delta I}{r_c}$$

$$\frac{r_g K - r_p \Delta I}{r_c} > \Delta C$$

$$r_g K > r_p \Delta I + r_c \Delta C$$

$$r_g > r_p \frac{\Delta I}{\Delta I + \Delta C} + r_c \frac{\Delta C}{\Delta I + \Delta C}$$



$$\frac{P B_1 + (1-P) B_2}{(1+r)}$$

MICROECONOMICS: THEORY AND APPLICATIONS

Abstracts and Lecture Summaries

for Professor Comanor's videotapes

ABSTRACTS AND SUMMARIES OF NINE VIDEOTAPED LECTURES
DELIVERED BY PROFESSOR WILLIAM COMMANOR

Lecture 1

Problem of Choice

Abstract

This lecture spells out the basic problem of rational decision making. A consumer's problem of choice is identified as consisting of two parts: (i) the preference ranking embodied in the utility function and (ii) the constraint (in the form of his budget restriction).

The consumer's optimization problem is formulated as a standard constrained maximization problem and the first-order condition for a maximum is derived. In particular, the value of the Lagrance multiplier is interpreted as the marginal utility of money. In another example of "ration coupons" λ is generalized as the shadow price of relaxing a constraint marginally.

Summary

The consumer's problem of choice is one of rational decisionmaking -- with special emphasis on rationality. The consumer's preferences indicate what he wants to achieve and are incorporated in his utility function. His budget constraint defines the restrictions on the decision process due to scarcity of resources.

Two parts of the problem of choice are: (i) preference ranking and (ii) constraints. We need to consider factors which influence (i) or (ii) or both.

The utility function: $u(q_1, q_2)$

Budget constraint: $y = p_1 q_1 + p_2 q_2$

or

$$q_1 = \frac{y}{p_1} - \frac{p_2}{p_1} q_2$$

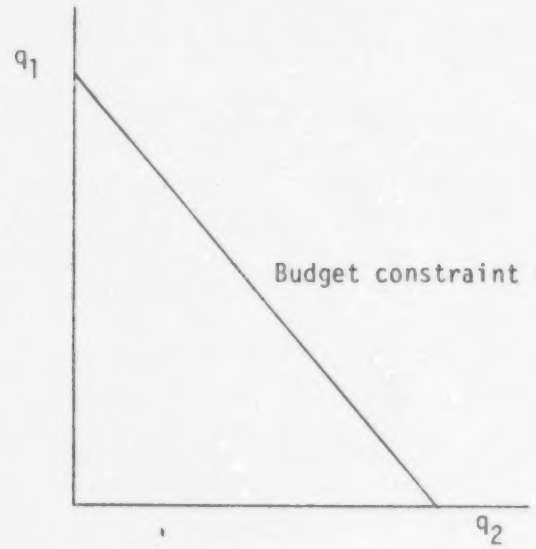


Figure 1.1 Budget constraint represented by straight line

A mathematical treatment (constrained maximization):

$$\max u(q_1,q_2) \quad \text{s.t. } y = p_1q_1 + p_2q_2$$

$L = u(q_1,q_2) + \lambda(y - p_1q_1 - p_2q_2)$ is the Lagrangian function

$$\frac{\partial L}{\partial q_1} = \frac{\partial u}{\partial q_1} - \lambda p_1 = 0 \; ; \quad \frac{\partial L}{\partial \lambda} = y - p_1q_1 - p_2q_2 = 0$$

$$\partial L/\partial q_2 = \partial u/\partial q_2 - \lambda p_2 = 0 \; ;$$

therefore

$$\frac{\partial u/\partial q_1}{\partial u/\partial q_2} = \frac{mu_1}{mu_2} = \frac{p_1}{p_2} \; .$$

Utility is maximized s.t. the budget constraint when ratio of the marginal utilities equals the price ratio.

$\frac{mu_1}{p_1} = \frac{mu_2}{p_2} = \lambda$. λ is the marginal utility of income available for spending. It is the effect on the utility function when the budget constraint is relaxed by an additional dollar.

In a situation of rationing λ would be the marginal utility of having another ration coupon. It is the shadow price of money/income in the usual consumer's allocation problem.

Lecture 2

Indifference Curves and Demand Curves

Abstract

Starting from the utility function this lecture defines an indifference curve as a locus of points denoting combinations of the two goods which correspond to the arbitrarily chosen constant utility level. The necessary conditions for utility maximization under budget constraint are presented geometrically as "tangency solution."

Sufficient conditions are stated (without proof) and linked with shape of indifference curves.

In the latter part of the lecture "traditional" demand curves are derived from the necessary conditions.

Summary

Two important considerations in the consumer's problem of choice are: (i) the objective function and (ii) the constraint. The problem

max $u(q_1,q_2)$ s.t. $y = p_1q_1 + p_2q_2$ leads to $\frac{mu_1}{mu_2} = \frac{p_1}{p_2}$ as necessary conditions. The utility function $u = u(q_1,q_2)$ can be held constant at an arbitrary level u^0 and for each such level we can obtain $q_1 = f(q_2)$. If u^0 is increased, for the same q_2 we need a higher q_1. Locus of combinations of q_1 and q_2 which yield same utility level is an indifference curve.

Since $u = u^0$, $du = 0$. But $du = \frac{\partial u}{\partial q_1} dq_1 + \frac{\partial u}{\partial q_2} dq_2$.

Thus $- \frac{\partial u}{\partial q_1} / \frac{\partial u}{\partial q_2} = \frac{dq_2}{dq_1}$ (for u = constant).

The MRS (marginal rate of substitution) $= \frac{dq_2}{dq_1} = - \frac{mu_1}{mu_2}$.

Also from first-order conditions, $\frac{mu_1}{mu_2} = \frac{p_1}{p_2}$. Thus slope of the indifference curve $\frac{dq_2}{dq_1} = - \frac{mu_1}{mu_2} = - \frac{p_1}{p_2}$ = slope of the budget line. Thus the necessary condition for an optimum is satisfied at the tangency solution (i.e., when the price line is tangent to an indifference curve).

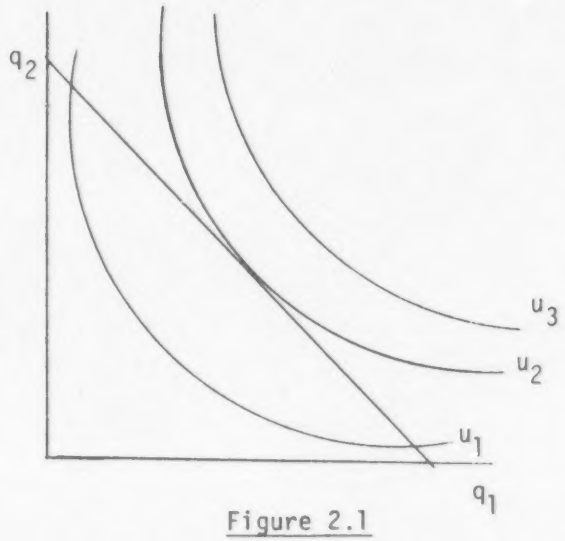


Figure 2.1

The sufficient conditions for utility maximization are that the bordered Hessian determinant

$$\begin{vmatrix} \frac{\partial^2 u}{\partial q_1^2} & \frac{\partial^2 u}{\partial q_1 \partial q_2} & -p_1 \\ \frac{\partial^2 u}{\partial q_1 \partial q_2} & \frac{\partial^2 u}{\partial q_2^2} & -p_2 \\ -p_1 & -p_2 & 0 \end{vmatrix} > 0$$

and both $\frac{\partial^2 u}{\partial q_1^2}$ and $\frac{\partial^2 u}{\partial q_2^2}$ are < 0 .

The determinant equals

$$2 \frac{\partial^2 u}{\partial q_1 \partial q_2} p_1 p_2 - \frac{\partial^2 u}{\partial q_1^2} p_2^2 - \frac{\partial^2 u}{\partial q_2^2} p_1^2 .$$

If $\frac{\partial^2 u}{\partial q_1 \partial q_2}$ is positive then $\frac{\partial^2 u}{\partial q_1^2} < 0$ and $\frac{\partial^2 u}{\partial q_2^2} < 0$ is sufficient.

This means mu_1 and mu_2 are declining. These second-order conditions are closely related to the shape of the underlying functions.

$\frac{d^2 q_1}{dq_2^2} > 0$ is consistent with this second-order condition.

Demand curves are derived essentially from the first-order conditions. When we solve the first-order conditions jointly the implicit solutions are:

$$\bar{q}_1 = f_1(p_1, p_2, y)$$

$$\bar{q}_2 = f_2(p_1, p_2, y)$$

$$\bar{\lambda} = f_3(p_1, p_2, y) .$$

The first two of these are the demand curves.

If in $\bar{q}_1 = f_1(p_1, p_2, y)$ we hold p_2 and y constant and let p_1 vary, we get the traditional demand curve. It should be noted that here the utility level is permitted to vary. When, on the other hand, we let p_1, p_2 and y vary but hold u constant, we get the compensated demand curve.

Lecture 3

Introduction to Demand Analysis

Abstract

Normal (i.e., traditional Marshallian) demand curve and compensated demand curve are compared and contrasted. In the standard indifference curve diagram price effect is decomposed into substitution effect and income effect. Construction of normal and compensated demand curves is shown in an accompanying diagram.

In the concluding part of this lecture the relation between price elasticity of normal demand, income elasticity of demand, budget share of the good and price elasticity of compensated demand is shown in the Slutsky equation. A numerical example follows to underscore the fact that usually the normal demand curve is more elastic than compensated demand curve.

Summary

Normal and Compensated Demand Curves

As we move along the normal demand curve (i.e., the usual Marshallian demand curve), while price falls the consumer's income and the prices of other goods remain unchanged. Different points on the demand curve imply different levels of utility for the consumer.

In the case of a compensated demand curve, when the price of the good in question falls the consumer's income and other prices are so changed as to keep the utility of the consumer constant. In Figure 3.1, RS is the initial price (i.e., budget) line and the equilibrium is at A. Now suppose p_2 and y remain constant but p_1 alone falls. RT is the new budget line and equilibrium is at C. The consumer's utility has increased from u_1 to u_2.

Decomposition of Price Effect

Substitution Effect:

Suppose utility is at $u^0 = u_1$. Now relative price changes, p_1 falls and p_2 rises such that (with the same level of y) UV (in Figure 3.1) is the new budget line and B is the equilibrium point. Movement from point A to B

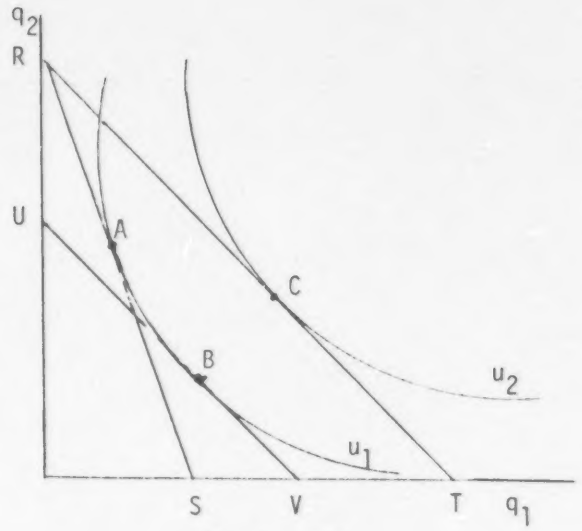


Figure 3.1

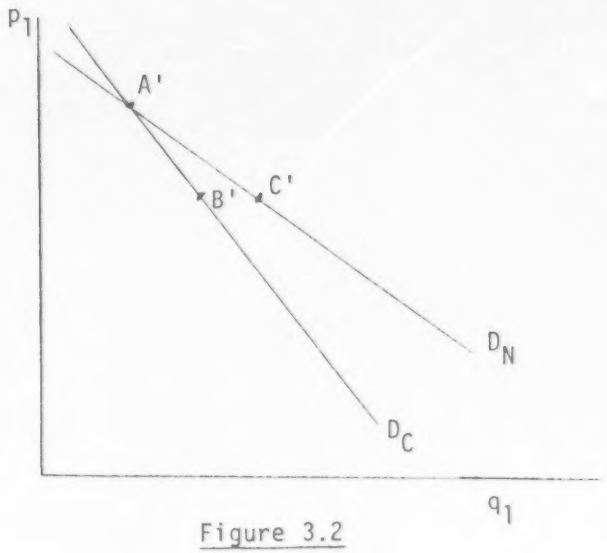


Figure 3.2

A' in Figure 3.2 corresponds to A in Figure 3.1 .

B' in Figure 3.2 corresponds to B in Figure 3.1 .

C' in Figure 3.2 corresponds to C in Figure 3.1 .

D_N: normal demand curve.

D_C: compensated demand curve.

(i.e., the change in q_1 associated with it) is the substitution effect.

Income effect measures the change caused by increase in income alone (when all prices remain constant). In Figure 3.1, the income effect is movement from B to C -- the increase in q_1 due to the fact that the consumer is better off because of a fall in p_1.

It may be noted that B is an hypothetical point. Normal demand curve shows movement from A to C in Figure 3.1 (or A' to C' in Figure 3.2). It incorporates both substitution effect and income effect.

Compensated demand curve incorporates only substitution effect, i.e., movement from A to B (in Figure 3.1) or A' to B' (in Figure 3.2).

Shape of normal demand curve:

$$\frac{\partial q_1}{\partial p_1} = \frac{\partial q_1}{\partial p_1}\bigg|_{u=\text{constant}} + \frac{\partial q_1}{\partial y}\frac{dy}{dp_1}$$

but $$\frac{dy}{dp_1} = -q_1 .$$

Thus $$\frac{\partial q_1}{\partial p_1} = \frac{\partial q_1}{\partial p_1}\bigg|_{u=\text{constant}} - q_1\frac{\partial q_1}{\partial y}$$

(Note: $\left.\frac{\partial q_1}{\partial p_1}\right|_{u=\text{constant}}$ is the slope of compensated demand curve.)

$$\frac{p_1}{q_1}\frac{\partial q_1}{\partial p_1} = \frac{p_1}{q_1}\frac{\partial q_1}{\partial p_1}\bigg|_{u=\text{constant}} - \frac{p_1}{q_1}\frac{\partial q_1}{\partial p_1}$$

or $$e_{ND} = e_{CD} - \frac{p_1 q_1}{y} e_y$$

is an alternative form of the Slutsky equation.

e_{ND} = elasticity of normal demand curve

e_{CD} = elasticity of compensated demand curve

e_y = income elasticity of demand

Example:

$$e_{ND} = -1.2 \qquad \frac{p_1 q_1}{y} = 0.1 \qquad e_y = 2 \ ,$$

therefore $e_{CD} = -1$.

The normal demand curve is more elastic than the compensated demand curve (because it shows both income effect and substitution effect).

Lecture 4

Marginal Utility of Income

Abstract

This lecture gives an interpretation of the Lagrange multiplier (λ) as the marginal utility of income. It is demonstrated that in the situation where marginal utility of income is constant: (i) indifference curves are vertically parallel, (ii) the income effect is zero and therefore (iii) the compensated and normal demand curves are identical.

Finally it is argued that even when income elasticity is not zero if the budget share of the good in question is very small the two demand curves are virtually identical.

Summary

It has been already derived (in an earlier lecture) that the first-order conditions for a consumer's optimization are $\partial u/\partial q_i = \lambda p_i$, i.e., marginal utility of good i = λ times its price. Here $\lambda = \partial u/\partial y$ is the marginal utility of income. This must hold for each good.

For any particular level of consumption of q_i (say q_i^0) total utility is the area underneath the marginal utility schedule [the shaded area in the diagram].

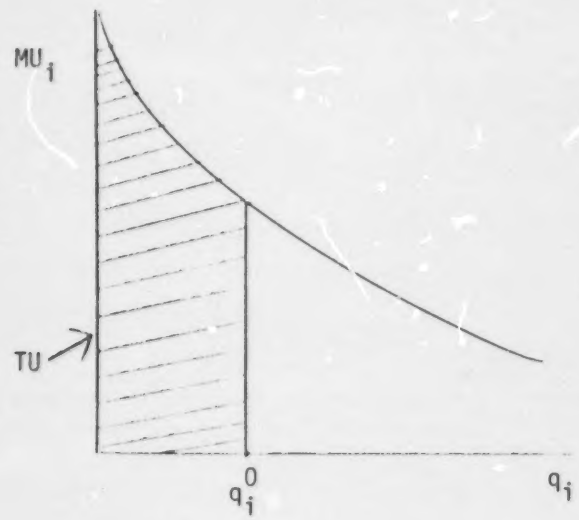


Figure 4.1

In reality we have the demand schedule and not the MU_i schedule. If, however, λ is constant, the MU_i is just the demand schedule multiplied by a constant.

Proof that λ is MU of money or income:

Suppose q is any particular good and y is a composite good representing all the remaining goods (i.e., income). Here OC is the amount of q purchased, AB is expenditure on q and OA = x is the income remaining. Price of q is p and price of y = 1. Then $x = y - pq$.

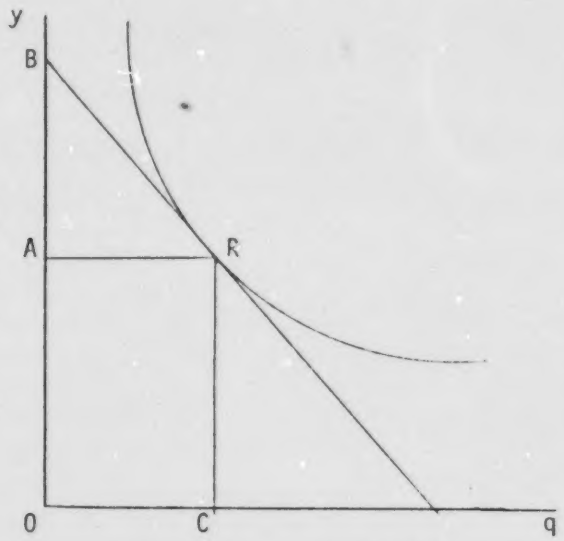


Figure 4.2

The consumer's problem is

$\max U(q,x)$

s.t. $y = pq + x$

$\delta = u(q,x) + \lambda(y - pq - x)$

$$\frac{\partial \delta}{\partial q} = \frac{\partial u}{\partial q} - \lambda p = 0$$

$$\frac{\partial \delta}{\partial x} = \frac{\partial u}{\partial x} - \lambda = 0$$

$$\frac{\partial \delta}{\partial \lambda} = y - pq - x = 0$$

Thus $\lambda = \frac{\partial u}{\partial x}$ = marginal utility of income.

Implications of constant marginal utility of income:

Assume that MU of income (λ) is constant. Characteristic of indifference curve in this case:

$$MRS = \frac{\partial u/\partial q}{\partial u/\partial x} = \frac{1}{\lambda} \frac{\partial u}{\partial q}$$

Here MRS depends only on MU of q and is constant when q is unchanged. In this diagram, the two indifference curves have the same slope at A and A'. In other

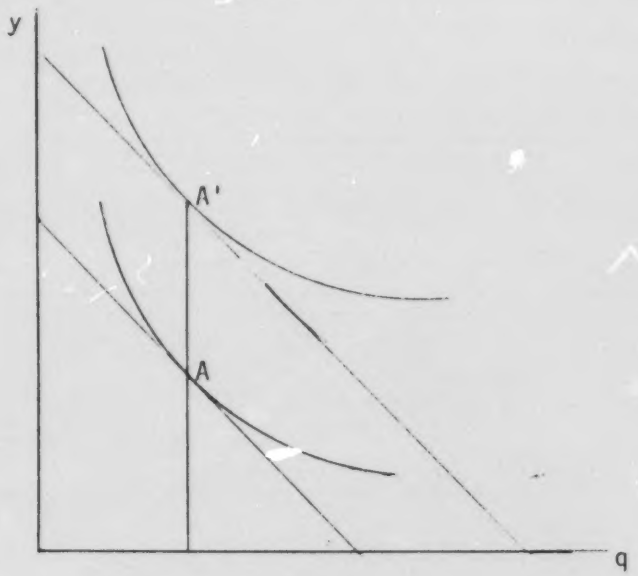


Figure 4.3

words, when marginal utility of income is constant the indifference curves are vertically parallel. It is evident that λ = constant implies income effect is zero. In such a situation the Normal Demand Curve and the Compensated Demand Curve would be identical.

$$e_{ND} = e_{CD} - \frac{pq}{y} e_y$$

When income effect is zero $e_y = 0$ and $e_{ND} = e_{CD}$. Both demand curves have the same price elasticity everywhere. Hence they are identical. If $e_y \neq 0$ but $\frac{pq}{y}$ = budget share of the good in question is very small. e_{ND} is approximately equal to e_{CD} and the two demand curves are more or less identical.

Lecture 5

Consumer's Surplus

Abstract

Starting from a definition of demand price this lecture identifies the area under the demand curve above the price line as consumer's surplus. Indifference curve analysis is used to give different interpretations of consumer's surplus.

In the latter part of the lecture rigorous mathematical derivations are used to show that the (Marshallian) triangle and the indifference curve measures of consumer's surplus are the same. It is noted that consumer's surplus is really the triangular area under compensated (rather than normal) demand curve.

Summary

Demand price is the maximum amount of money a consumer is willing to spend for a unit of the good rather than do without it. In this figure, the consumer is willing to pay a price p_a for unit q_1 of the commodity.

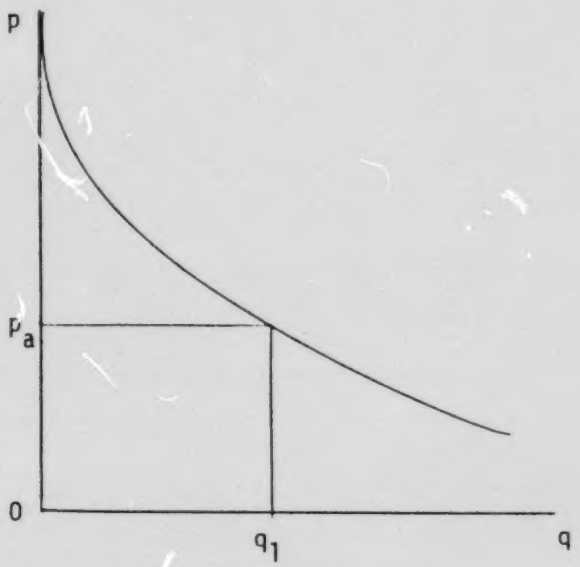


Figure 5.1

For example, a consumer is willing to pay less and less for each successive bottle of beer. The total benefit derived from q_1 units is the area under the demand curve (up to q_1). The outlay is the rectangular area under the

price line (up to q_1).

Consumer's surplus = total benefit - total outlay = upper triangular area.

Assume that MU of income (λ) is constant. MRS at point C = MRS at point A (because indifference curves are vertically parallel). The initial income of the consumer is OM. His demand is q_1. Points M and C are on the same indifference curve. The consumer could at most pay BC for the quantity Oq_1 and still remain as well off as at the beginning. But he pays only AB amount. Thus AC is his consumer's surplus.

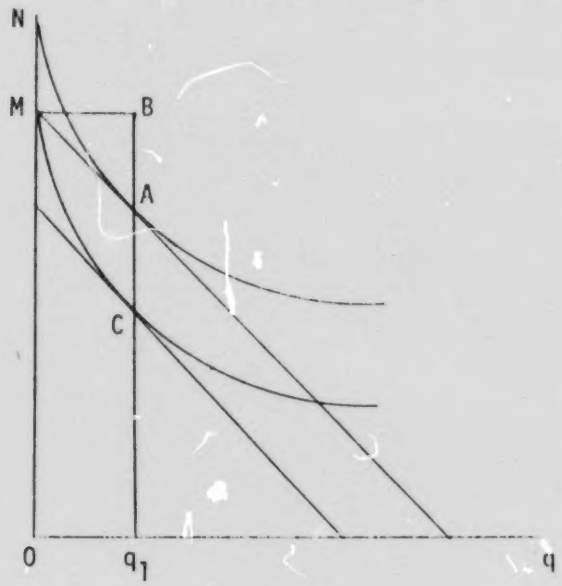


Figure 5.2

Alternative definition of consumer's surplus:

Compensation to be paid to consumer if the good is withdrawn from the market. Since points A and N are on the same indifference curve the required amount would be MN. If indifference curves are vertically parallel MN = AC. This holds when MU of income (λ) is constant.

$u = u(q,y)$

$du = \frac{\partial u}{\partial q} dq + \frac{\partial u}{\partial y} dy = 0$ along an indifference curve

$$\frac{\partial u/\partial q}{\partial u/\partial y} = MRS = -\frac{dy}{dq} = p_q$$

$q = f(p_q, y)\,\big|_{u = \text{constant}}$ is the compensated demand curve

$p_a = f^{-1}(q, y)\,\big|_{u = \text{constant}}$ is the inverse (compensated) demand function

Hence:

$$-\frac{dy}{dq} = f^{-1}(q, y)\,\big|_{u = \text{constant}}$$

or

$$y = \int_0^{q_1} f^{-1}(q, y)\,\big|_{u = \text{constant}}\, dq = BC$$

$$AC = \int_0^{q_1} f^{-1}(q, y)\,\big|_{u = \text{constant}}\, dq - AB$$

which is the same as the triangular area below the (compensated) demand curve above the price line.

If income effect could be ignored, consumer's surplus is the triangular area under the demand curve (theoretically it should be under the compensated demand curve).

In public expenditure analysis what we have is normal and not the compensated demand. This is a difficulty in measuring consumer's surplus.

Lecture 6

Theory of Exchange

Abstract

This lecture deals with a two-person two-good exchange model. Allocations are represented by points in a box diagram. Starting from an initial allocation the area of negotiation is identified as the "cigar-shaped" region bounded by the two initial indifference curves of the individuals. Tangency solution is shown to lead to an optimal allocation.

The contract curve is defined as locus of all efficient allocations. The segment of the contract curve inside the cigar-shaped area is emphasized as the relevant set of optimal allocations. A point on the contract curve is regarded as conforming to an economist's notion of efficiency.

Summary

We consider interaction between two consumers with fixed endowments of two goods.

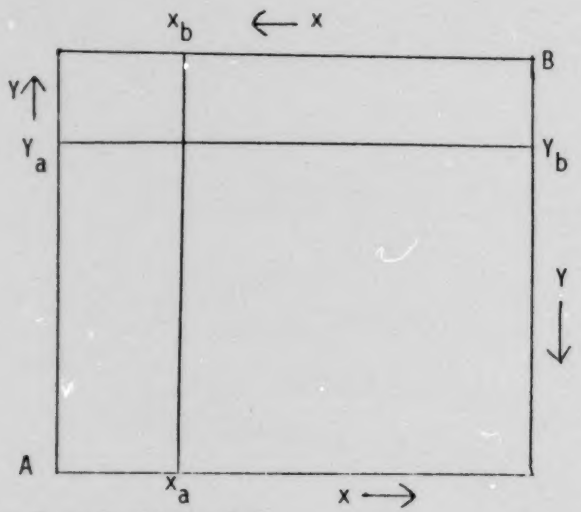


Figure 6.1

$X_a + X_b$ = total endowment of X

$Y_a + Y_b$ = total endowment of Y

Every point in the box in Figure 6.1 represents a specific allocation of the two goods between the individuals A and B. P is the starting point. Exchange results in reallocation and depends on the individual's preferences.

In Figure 6.2, P' is a better allocation than P because A moves to indifference curve A_2 from A_1 and B moves up to B_2 from B_1. Both parties are

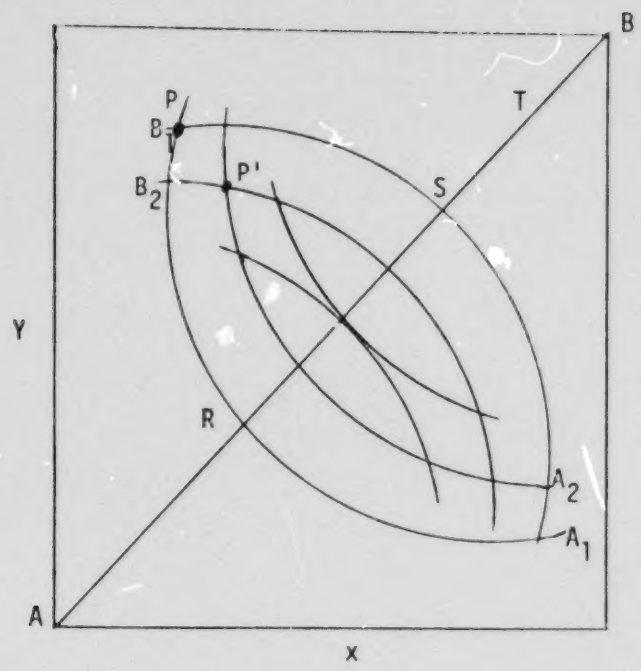


Figure 6.2

better off. At P' there is room for further improvement. We stop at a point inside the cigar-shaped area (bounded by the indifference curves A_1 and B_1) where two indifference curves are tangent. Note here again we get a tangency solution but this time it is between two indifference curves and not between an indifference curve and a price line.

Contract Curve

Locus of all such tangency points is inside the box. The line segment RS consists of all such points which lie inside the cigar-shaped area. Movement along RS implies A is better off only when B becomes worse off. An efficient point is an allocation where an improvement (in the sense that the utility of one individual should rise without any associated fall in utility of the other) is not possible. Points on the contract curve are all efficient points.

Given the starting point P, RS is the relevant stretch of the contract curve. Outside this region one person is made worse off compared to the

starting point P and trade does not take place. But any point on RS is better than P.

P and T cannot be compared although T is a point on the contract curve. At point T, A is far better off but B is much worse off compared to the initial allocation P. Hence trade does not take place.

In conclusion, it may be emphasized that the contract curve defines the economist's notion of allocative efficiency.

Lecture 7

Introduction to the Theory of the Firm

Abstract

In this lecture, profit maximization (rather than utility maximization) is introduced as the objective for firm behavior. Competitive and monopolistic market situations are distinguished and necessary (and sufficient) conditions are derived for each situation to emphasize the difference in optimal firm behavior in different markets. In particular, while competition requires P = MC, in a monopolistic situation MR = MC and price exceeds marginal cost. Compared to monopoly, competition is shown to result in lower price and higher output.

The deadweight welfare loss in monopoly as compared to competition is shown graphically. The special assumptions needed (i.e., no income effect and a long-run competitive equilibrium as benchmark) are stated.

The lecture ends with a summary recapitulation of the above results.

Summary

Profit maximization rather than utility maximization is motivation for behavior of firms.

Profit = revenue - cost = $\pi = pq - c$

Two types of market situations may be distinguished:

(a) competitive market where price is independent of the firms output

(b) monopolistic market where price depends on quantity sold

Competitive markets:

$$\pi = pq - c(q)$$

$$\frac{d\pi}{dq} = p - \frac{dc}{dq} = 0 \quad \text{or} \quad p = MC \quad \text{(necessary condition)}$$

$$\frac{d^2\pi}{dq^2} = -\frac{d^2c}{dq^2} < 0 \quad \text{or} \quad \frac{d^2c}{dq^2} > 0 \quad \text{(sufficient condition)}$$

This requires that MC must be rising.

Monopolistic markets:

$$p = f(q), \quad \frac{dp}{dq} < 0 \quad \text{(here price depends on quantity)}$$

$$\pi = pq - c(q)$$

$$\frac{d\pi}{dq} = p + q\frac{dp}{dq} - \frac{dc}{dq} = 0$$

or

$$p + q\frac{dp}{dq} = MC$$

Since $\frac{dp}{dq} < 0$ it means $P > MC$. Thus in noncompetitive markets price exceeds MC.

$$\pi = R(q) - c(q)$$

$$\frac{d\pi}{dq} = \frac{dR}{dq} - \frac{dC}{dq} = 0 \quad \text{or} \quad MR = MC \quad \text{(necessary condition)}$$

$$\frac{d^2\pi}{dq^2} = \frac{d^2R}{dq^2} - \frac{d^2C}{dq^2} < 0$$

This sufficient condition is satisfied when MR is falling and MC is rising.

In this diagram:

P_c is competitive price and q_c is competitive output (P = MC)

P_m is monopoly price and q_m is monopoly output (MR = MC)

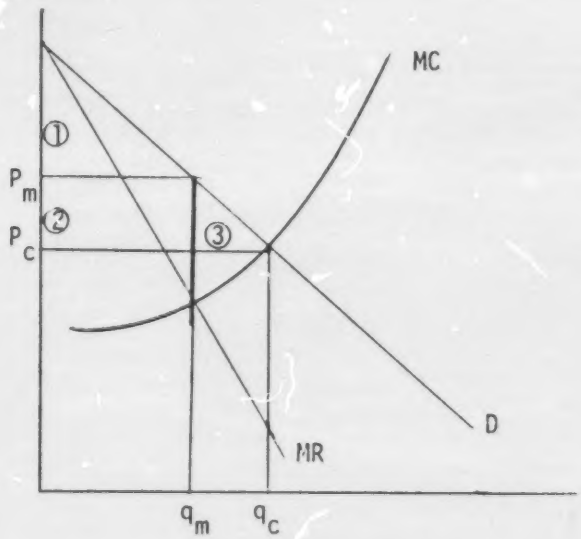


Figure 7.1

Note $P_m > P_c$ and $q_m < q_c$. Monopoly reduces output and increases price.

In a competitive situation consumer's surplus is (1) + (2) + (3). Under monopoly consumer's surplus is (1) only. Area (2) = monopoly output × price differential (in a long-run equilibrium situation). Area (2) = profit. But Area (3) is a loss in consumer's surplus not gained by producers. This represents dead weight loss to society due to monopoly.

Qualifications

1. P_c and q_c must be a long-run competitive equilibrium so that AC = MC Only in this case Area (2) is really the profit.
2. Income effect is ignored so that consumer's surplus can be measured from the normal demand curve.

In short, (i) firm behavior depends on the type of market -- competitive or monopolistic; (ii) $P_m > P_c$ and $q_m < q_c$, and (iii) if we ignore income effect the dead weight loss of monopoly can be measured.

Lecture 8

Production Function and Demand for Inputs

Abstract

This lecture deals with the role of the production function in production theory and derives the input demand functions of a profit maximizing firm. The first-order conditions of profit maximization are stated as input price equal to marginal revenue product. It is emphasized that each demand function is obtained from joint solution of all first-order conditions.

A geometric example is given to show how change in one input price affects MRP of all inputs and through interactive changes leads to an increase in its demand more than is implied by its MRP schedule.

In conclusion, it is emphasized that (i) MRP schedules are not input demand schedules and (ii) the input demand schedules derived from them are generally more elastic.

Summary

In firm theory, production function is analogous to utility function in consumer behavior. Production function is a way of describing the production process:

q = output, x_1 and x_2 are inputs

Production function: $q = f(x_1, x_2)$

Profit = Revenue - Cost

$$\pi = R(q) - w_1 x_1 - w_2 x_2 - F$$

Here F is fixed cost, w_1 and w_2 are input prices. We want to find the firm's demand for x_1 and x_2.

$$\frac{\partial \pi}{\partial x_1} = \frac{\partial R}{\partial q} \frac{\partial f}{\partial x_1} - w_1 = 0$$

$$\frac{\partial \pi}{\partial x_2} = \frac{\partial R}{\partial q} \frac{\partial f}{\partial x_2} - w_2 = 0$$

or

$$MR \cdot MP_1 = w_1$$

$$MR \cdot MP_2 = w_2$$

In other words, $MRP_i = w_i$ $(i = 1,2)$, i.e., factor price = marginal revenue product.

The demand schedule for each input is derived from joint solution of the first-order conditions for all inputs. Input demand functions are derived demands from the output level.

Relation Between MRP Schedules and Input Demand Functions

(1) MRP schedule is defined by holding quantities of other inputs fixed.

(2) Factor demand schedule is defined by holding prices of other inputs fixed.

Example: Suppose w_1 falls and w_2 remains constant.

(i) As w_1 falls MRP_1 falls to maintain equality

(ii) This leads to an increase in x_1

(iii) This leads to an increase in x_2

(iv) This leads to an increase in MRP_1 (i.e., MRP_1 shifts out) which causes a secondary increase in x_1.

Thus because of a fall in w_1, demand for x_1 increases by a larger quantity than indicated by MRP_1. Input demand schedule is generally more elastic than the MRP schedule.

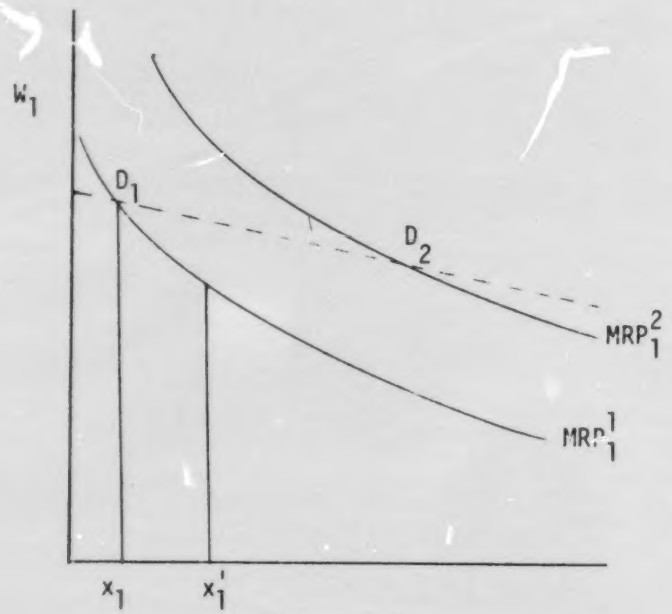


Figure 8.1

[Note that in this diagram the subscript refers to factor 1. The superscript refers to period or stage.]

In conclusion we may note that:

(1) $MRP_i = w_i$

(2) MRP schedule is not itself the input demand curve

(3) Input demand schedules are typically more elastic than MRP schedules from which they are derived.

Lecture 9

Principles of Efficient Pricing

Abstract

This lecture considers the problem of social optimization. Social welfare is measured by the excess of social benefits over social cost. Further social benefits can be measured by total revenue plus consumer's surplus and social costs may be regarded as identical to private costs. It is then demonstrated mathematically that the competitive policy of marginal cost pricing is also socially optimal. An accompanying diagram shows the competitive optimum.

The lecture considers the problem of capacity (expansion) cost and the shadow price of capacity is defined in the constrained optimization context.

It is argued that when the shadow price of capacity exceeds marginal capacity cost, capacity expansion is desirable. In the opposite case capacity should be reduced.

Finally the problem of normal and off peak demand is considered and it is advised that only peak period demand should contribute to capacity costs and normal demand should optimally pay for operating costs alone.

Summary

This lecture considers the problem of optimization from the point of view of society. The individual consumer tries to maximize utility. The firm maximizes profit. Society maximizes net social benefits.

Maximization of Social Welfare

Social Welfare = Social Benefits - Social Costs

Social Benefits = Total Revenue + Consumer's Surplus
= Area Under the Demand Curve

Social costs can be taken to be the total costs if we assume that costs are identical for firms and society.

$W + TR + S - TC$ where W = social welfare
TR = total revenue
S = consumer's surplus
TC = total cost

$$\frac{dw}{dq} = \frac{d(TR + S)}{dq} - \frac{dTC}{dq} = 0$$

$$TR + S = \int_0^q p(q)dq \quad \text{and} \quad \frac{d(TR + S)}{dq} = p$$

Therefore social maximum welfare implies $p = MC$. Recall that competitive market optimization implies $p = MC$, the same as social optimum. In this diagram, competitive output q_c is socially optimal.

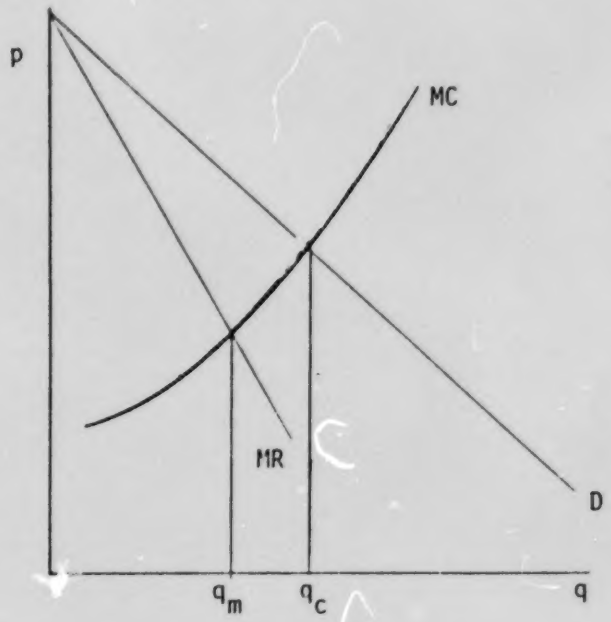


Figure 9.1

Complications Due to Capacity Constraint

Total costs consist of

(a) capacity cost [β per unit, say]

(b) operating cost [b per unit, say]

Thus

$$TC = (b + \beta)q$$

$$MC = b + \beta$$

Now we introduce capacity constraint $\bar{Q}$.

$$\max w = TR + S - TC$$

$$\text{s.t.} \quad q \leq \overline{Q}$$

$$\delta(q,\lambda) = TR + S - bq - \lambda(q - \overline{Q})$$

Assume capacity constraint is binding. Then

$$\frac{\partial \delta}{\partial q} = p - b - \lambda = 0$$

or

$$p = b + \lambda$$

$$\frac{\partial \delta}{\partial \lambda} = q - \overline{Q} = 0 \text{ , i.e., } q = \overline{Q}$$

In this case, price is greater than marginal operating cost. λ is the shadow price of capacity.

If the constraint is not binding, $\lambda = 0$ and $p = b$ = marginal operating cost. If constraint is binding $\lambda > 0$ and $p > b$ so that optimum price exceeds marginal operating cost.

Question of Capacity Expansion

Shadow price of capacity = λ , which is the increase in welfare if capacity constraint is marginally relaxed. β is the (actual) cost of building capacity. If $\lambda > \beta$, we should expand capacity. If $\lambda < \beta$, we should reduce capacity.

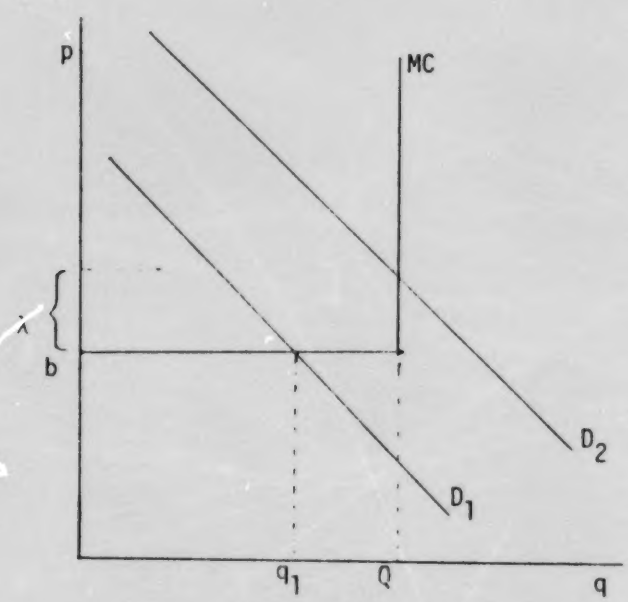


Figure 9.2

$MC = b$ when $0 \leq q \leq \bar{Q}$

for $q > \bar{Q}$, MC goes to infinity

When demand curve is D_1, capacity constraint is not binding. For demand curve D_2, the constraint is binding. In such a situation market clearing price is $(b + \lambda)$. In certain situations both demand curves may exist. For example, D_1 may be normal (off peak) demand and D_2 may be peak demand.

The general pricing rule should be that only peak demand should contribute to capacity cost and normal demand should pay for operating cost only.

peak period price = $b + \lambda$

off peak price = b

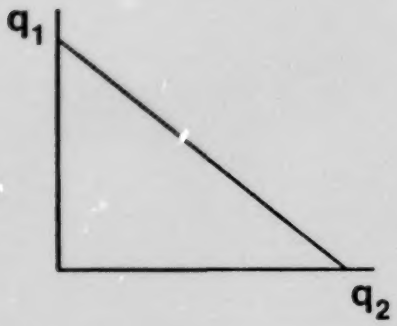
MICROECONOMICS: THEORY AND APPLICATIONS

Lecture Notes for Professor Comanor's

videotapes

$U(q_1, q_2)$

$y = p_1 q_1 + p_2 q_2$



$$q_1 = \frac{y}{p_1} - \frac{p_2}{p_1} q_2$$

Max: $U(q_1, q_2)$

Subject to: $y = p_1 q_1 + p_2 q_2$

$$L = U(q_1, q_2) + \lambda \left[y - p_1 q_1 - p_2 q_2 \right]$$

$$\frac{\partial L}{\partial q_1} = \frac{\partial U}{\partial q_1} - \lambda p_1 = 0$$

$$\frac{\partial L}{\partial q_2} = \frac{\partial U}{\partial q_2} - \lambda p_2 = 0$$

$$\frac{\partial L}{\partial \lambda} = y - p_1 q_1 - p_2 q_2 = 0$$

$$\frac{\partial U}{\partial q_1} = \lambda p_1$$

$$\frac{\partial U}{\partial q_2} = \lambda p_2$$

$$y = p_1 q_1 + p_2 q_2$$

$$\frac{MU_1}{MU_2} = \frac{p_1}{p_2}$$

$$MU_1 = \lambda p_1 \quad \text{or} \quad \frac{MU_1}{p_1} = \lambda$$

$$MU_2 = \lambda p_2 \quad \text{or} \quad \frac{MU_2}{p_2} = \lambda$$

$$\frac{MU_1}{P_1} = \frac{MU_2}{P_2}$$

Maximize: $U(q_1, q_2)$

subject to: $y = p_1 q_1 + p_2 q_2$

$$\frac{MU_1}{MU_2} = \frac{P_1}{P_2}$$

$$U^\circ = U(q_1, q_2)$$

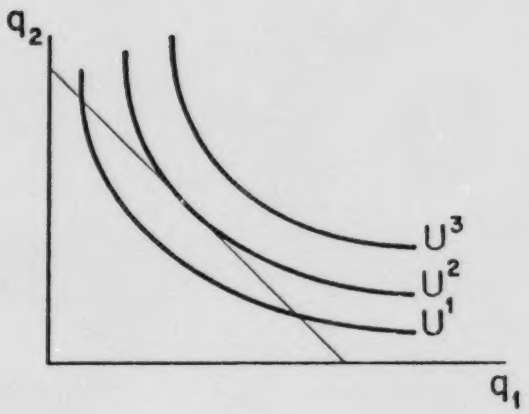
$q_1 = f(q_2)$ for Utility held constant

$$U = U(q_1, q_2)$$

$$dU = \frac{\partial U}{\partial q_1} dq_1 + \frac{\partial U}{\partial q_2} dq_2 = 0$$

$$-\frac{\frac{\partial U}{\partial q_1}}{\frac{\partial U}{\partial q_2}} = \frac{dq_2}{dq_1} \text{ for Utility held constant}$$

$$-\frac{MU_1}{MU_2} = MRS = \frac{dq_2}{dq_1}$$



$$\frac{MU_1}{MU_2} = MRS = -\frac{P_1}{P_2}$$

Second order conditions:

$$\begin{vmatrix} \frac{\partial^2 U}{\partial q_1^2} & \frac{\partial^2 U}{\partial q_1 \partial q_2} & -p_1 \\ \frac{\partial^2 U}{\partial q_2 \partial q_1} & \frac{\partial^2 U}{\partial q_2^2} & -p_2 \\ -p_1 & -p_2 & 0 \end{vmatrix} > 0$$

$$2\frac{\partial^2 U}{\partial q_1 \partial q_2} p_1 p_2 - \frac{\partial^2 U}{\partial q_1^2} p_2^2 - \frac{\partial^2 U}{\partial q_2^2} p_1^2 > 0$$

$$\frac{\partial^2 U}{\partial q_1^2} < 0 \text{ and } \frac{\partial^2 U}{\partial q_2^2} < 0$$

$$\frac{\partial L}{\partial q_1} = \frac{\partial U}{\partial q_1} - \lambda p_1 = 0$$

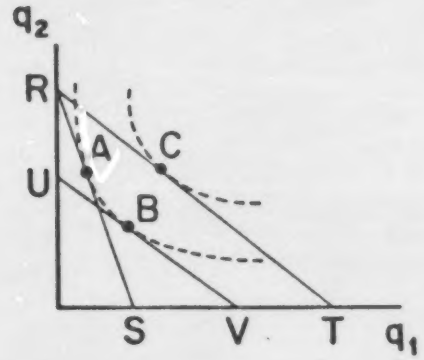
$$\frac{\partial L}{\partial q_2} = \frac{\partial U}{\partial q_2} - \lambda p_2 = 0$$

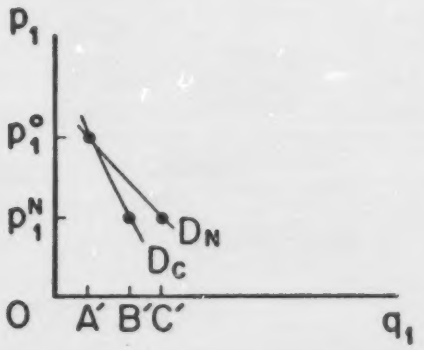
$$\frac{\partial L}{\partial \lambda} = y - p_1 q_1 - p_2 q_2 = 0$$

$$\bar{q}_1 = f_1(p_1, p_2, y)$$

$$\bar{q}_2 = f_2(p_1, p_2, y)$$

$$\bar{\lambda} = f_3(p_1, p_2, y)$$





$$\frac{\partial q_1}{\partial p_1} = \left.\frac{\partial q_1}{\partial p_1}\right|_{\text{U CONSTANT}} + \frac{\partial q_1}{\partial y}\,\frac{dy}{dp_1}$$

$$dy = -dp_1 \cdot q_1$$

$$\frac{dy}{dp_1} = -q_1$$

$$\frac{\partial q_1}{\partial p_1} = \left.\frac{\partial q_1}{\partial p_1}\right|_{\text{U CONSTANT}} - q_1\frac{\partial q_1}{\partial y}$$

$$\frac{p_1}{q_1}\,\frac{\partial q_1}{\partial p_1} = \left.\frac{p_1}{q_1}\,\frac{\partial q_1}{\partial p_1}\right|_{\text{U CONSTANT}} - \frac{p_1}{q_1}\,q_1\frac{\partial p_1}{\partial y}$$

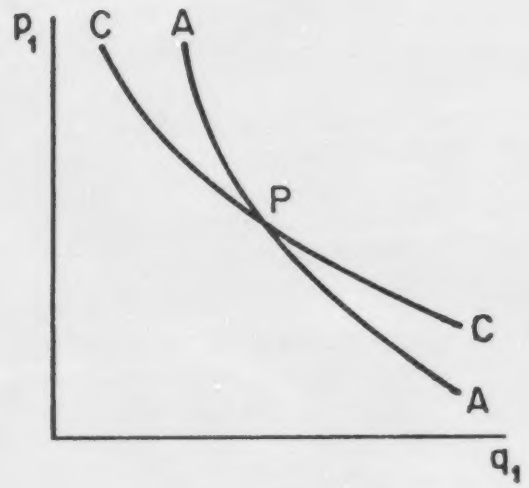
$$e = \frac{\frac{\Delta q}{q}}{\frac{\Delta p}{p}} = \frac{\Delta q}{q} \cdot \frac{p}{\Delta p} = \frac{\Delta q}{\Delta p} \cdot \frac{p}{q}$$

$$= \frac{\partial q}{\partial p} \cdot \frac{p}{q}$$

$$e_{ND} = e_{CD} - p_1 \frac{q_1}{y} \frac{y}{q_1} \frac{\partial q_1}{\partial y}$$

$$e_{ND} = e_{CD} - \frac{p_1 q_1}{y} e_y$$

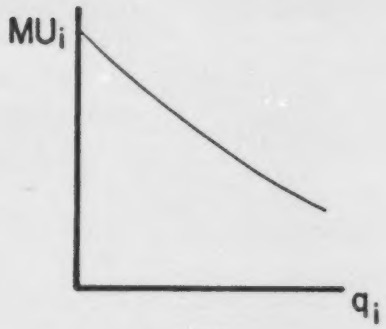
The Slutsky Equation



First order conditions: $\frac{\partial U}{\partial q_i} = \lambda p_i$

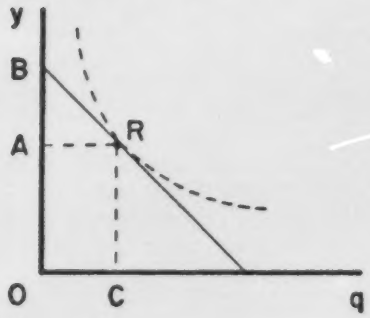
Where $\lambda = \frac{\partial U}{\partial y}$

Second order conditions: $\frac{\partial^2 U}{\partial q_i^2} < 0$



Total utility is area under marginal utility schedule.

If λ is a constant, marginal utility schedule equals the demand schedule multiplied by a constant.



Income = OB;
Amount spent on good = AB;
Amount remaining = AO,
which is spent on other goods and services;
Amount of this good purchased = OC;
Amount of other goods and services purchased = AO = x,
since composite price of all other goods = 1.

$x = y - pq$

Maximize: $U(q,x)$

subject to: $y = pq + x$

$$L = U(q,x) + \lambda[y - pq - x]$$

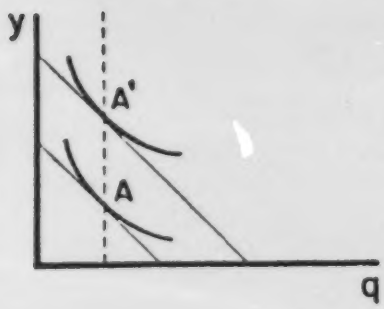
$$\frac{\partial L}{\partial q} = \frac{\partial U}{\partial q} - \lambda p = 0$$

$$\frac{\partial L}{\partial x} = \frac{\partial U}{\partial x} - \lambda = 0$$

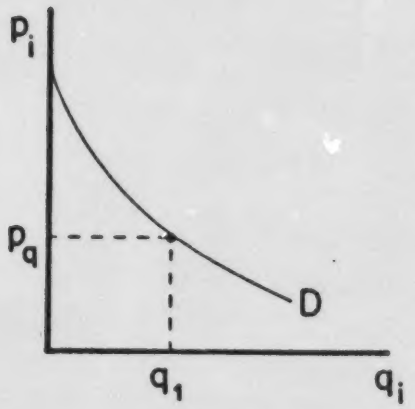
$$\frac{\partial L}{\partial \lambda} = y - pq - x = 0$$

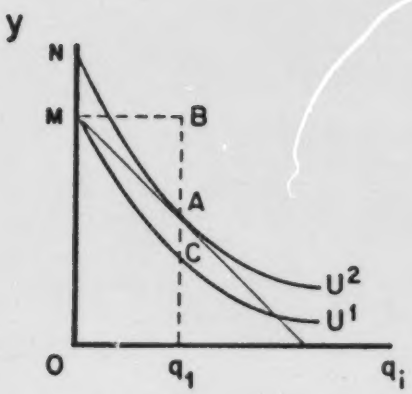
$$\frac{\partial U}{\partial x} = \lambda$$

$$MRS = \frac{\frac{\partial U}{\partial q}}{\frac{\partial U}{\partial x}} = \frac{\partial U}{\partial q} \cdot \frac{1}{\lambda}$$



$$e_{ND} = e_{CD} - \frac{p_i q_i}{y} e_y$$





MRS at C = MRS at A because λ is constant.

Income = OM;

Amount spent on good = AB;

Quantity purchased = q_1

$$\frac{MU_q}{MU_y} = p_q \qquad \text{since } p_y = 1$$

$U(q,y)$

$$dU = \frac{\partial U}{\partial q}\, dq + \frac{\partial U}{\partial y}\, dy = 0$$

$$-\frac{dy}{dq} = \frac{\frac{\partial U}{\partial q}}{\frac{\partial U}{\partial y}} = MRS = p_q$$

$$q = f(p_q, y)\Big|_{U \text{ CONSTANT}}$$

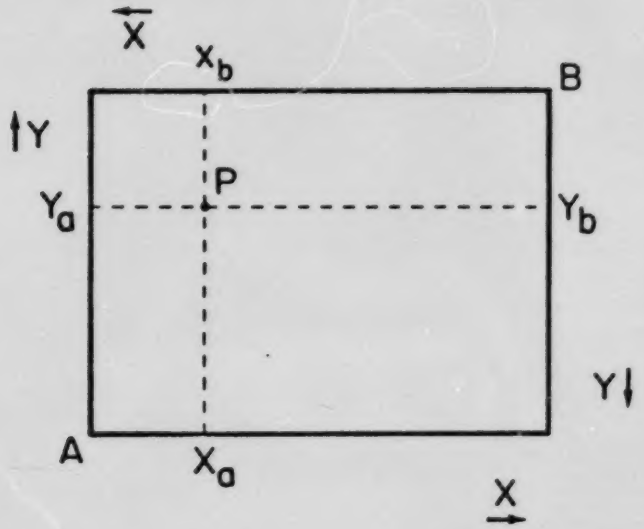
$$p_q = f^{-1}(q,y)\Big|_{U \text{ CONSTANT}}$$

$$p_q = -\frac{dy}{dq}$$

$$-\frac{dy}{dq} = f^{-1}(q,y)\Big|_{U \text{ constant}}$$

$$y = \int_c^{q_1} f^{-1}(q,y)\Big|_{U \text{ constant}} dq = BC$$

$$BC - AB = AC = \int_0^{q_1} f^{-1}(q,y)\Big|_{U \text{ constant}} dq - p_q\, q_1$$

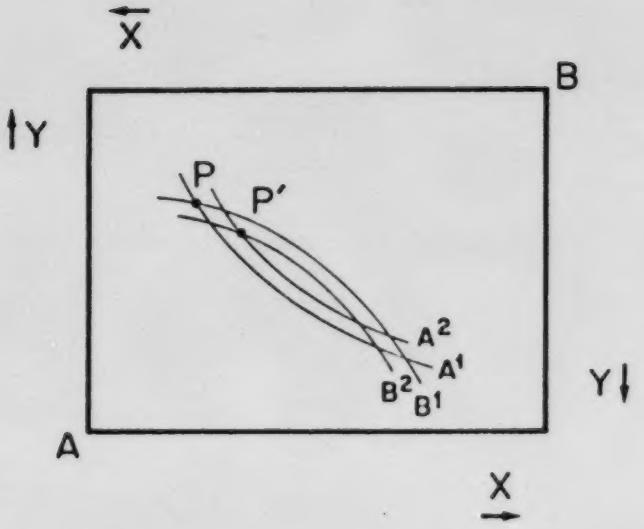


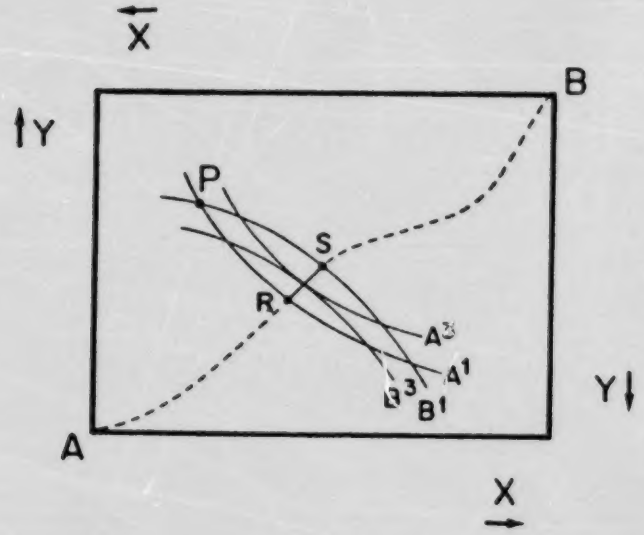
Two consumers: A and B

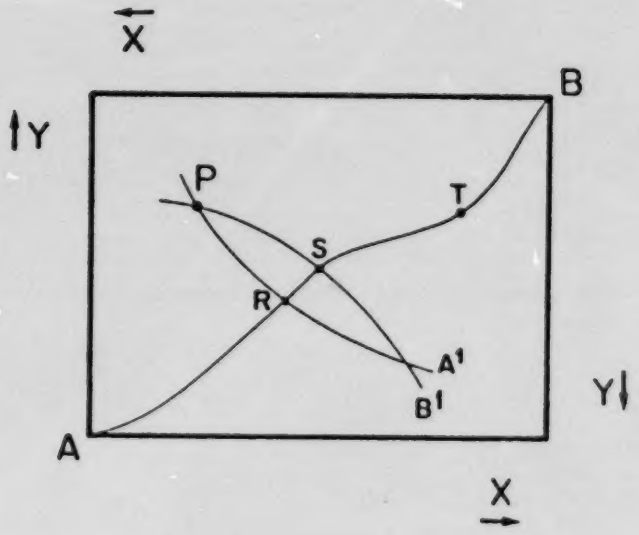
Two goods: X and Y

$\bar{X} = X_a + X_b$

$\bar{Y} = Y_a + Y_b$




X
B
Y
P
S
R
A3
A1
B3
B1
Y
A
X


X
B
Y
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T
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R
A1
B1
Y
A
X

Profit maximization rather than Utility maximization.

Profits = Revenues minus Costs.

$$\pi = pq - C$$

Two types of market situations:

a) price is fixed - competitive market.

b) price depends on quantity sold - monopolistic market.

Firm behavior in competitive markets
price is fixed

$$\pi = pq - C(q)$$

$$\frac{d\pi}{dq} = p - \frac{dC}{dq} = 0$$

$$p = MC$$

$$\frac{d^2\pi}{dq^2} = -\frac{d^2C}{dq^2} < 0 \text{ or } \frac{d^2C}{dq^2} > 0$$

Firm behavior in monopolistic markets

price depends on quantity

$p = f(q)$ where $\frac{dp}{dq} < 0$

$\pi = pq - C(q)$

$$\frac{d\pi}{dq} = p + q\frac{dp}{dq} - \frac{dC}{dq} = 0$$

$$p + q\frac{dp}{dq} = MC$$

Since $\frac{dp}{dq} < 0$, second term is negative,

and $p > MC$

Revenue $= pq$

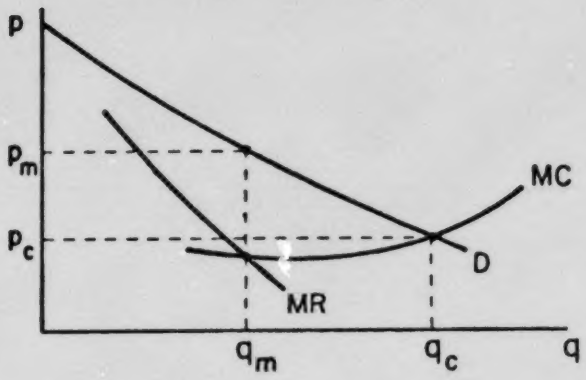
$\pi = R(q) - C(q)$

$$\frac{d\pi}{dq} = \frac{dR}{dq} - \frac{dC}{dq} = 0$$

$MR = MC$

$$\frac{d^2\pi}{dq^2} = \frac{d^2R}{dq^2} \quad \frac{d^2C}{dq^2} < 0$$

Satisfied when MR is decreasing and MC is increasing.



Under competition:

consumer surplus = ① + ② + ③

Under monopoly:

consumer surplus = ①

profits = ②

Dead weight loss of monopoly = ③

Production functions rather than Utility functions.

$q = f(x_1, x_2)$

where x_1 and x_2 are two inputs in the production process.

Production function is a way of describing the production process.

Profits = Revenues minus costs.

$$\pi = R(q) - w_1 x_1 - w_2 x_2 - F$$

$$\frac{\partial \pi}{\partial x_1} = \frac{\partial R}{\partial q} \frac{\partial f(x_1, x_2)}{\partial x_1} - w_1 = 0$$

$$\frac{\partial \pi}{\partial x_2} = \frac{\partial R}{\partial q} \frac{\partial f(x_1, x_2)}{\partial x_2} - w_2 = 0$$

$$MR \cdot MP_i = w_i \quad \text{or} \quad MRP_i = w_i$$

Demand schedules for each input derived from joint solution of first order conditions for all inputs.

These demands are <u>derived</u> from demand for product.

Relationship between MRP schedule and the demand schedule for an input:

MRP schedule defined by holding <u>quantities</u> of other inputs fixed.

Demand schedule defined by holding <u>prices</u> of other inputs fixed.

Consider chain of events following a decline in w_1, holding w_2 constant:

a) decline in w_1 leads to a decline in MRP_1; (to maintain equality)

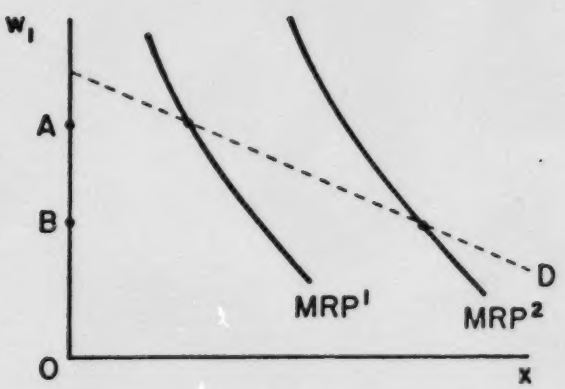
b) ... leads to an increase in x_1;

c) ... leads to an increase in MRP_2;

d) ... leads to an increase in x_2;

e) ... leads to an increase in MRP_1 and of x_1

Greater increase in quantity of first input than indicated by MRP schedule.



Demand schedules for inputs generally more elastic than MRP schedules from which they are derived.

Maximization of social welfare:

a) social benefits = total revenue + consumer surplus.
- area under demand curve

b) social costs = total costs

$$W = TR + S - TC$$

$$\frac{dW}{dq} = \frac{d}{dq}(TR + S) - \frac{d}{dq} TC = 0$$

$$TR + S = \int_0^q p(q)dq \text{ and } \frac{d}{dq}(TR+S) = p$$

$$p = MC$$

Let total costs be comprised of:

a) capacity costs of β per unit; and

b) operating costs of b per unit.

$$TC = (b + \beta)q$$

$$MC = b + \beta$$

Now let there be a capacity constraint, $\bar{Q}$, and consider what is the optimal price to maximize social welfare.

$W = TR + S - TC$

subject to: $q \leq \bar{Q}$

$$L(q, \lambda) = (TR + S) - bq - \lambda \left[q - \bar{Q}\right]$$

$$\frac{\partial L}{\partial q} = p - b - \lambda = 0$$

$$p = b + \lambda$$

$$\frac{\partial L}{\partial \lambda} = q - \bar{Q} = 0 \quad \text{or} \quad q = \bar{Q}$$

If constraint is not binding:

$\lambda = 0$ and $p = b$ = marginal operating costs.

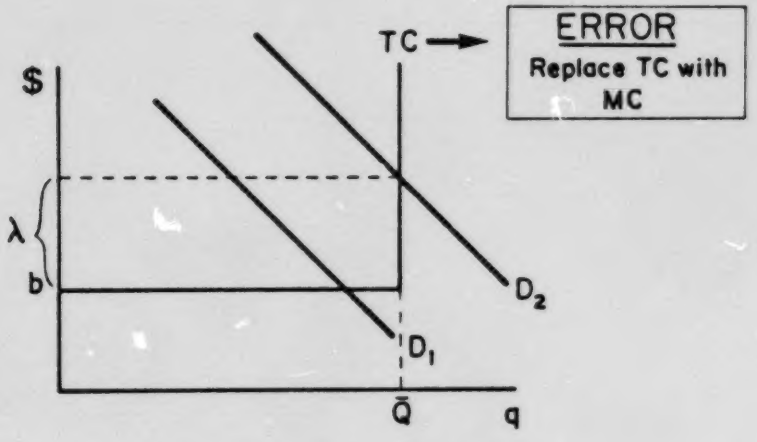
If constraint is binding:

$\lambda > 0$ and $p > b$.

Optimal price should exceed marginal operating costs in presence of a capacity constraint.

If $\lambda > \beta$, should expand capacity.

If $\lambda < \beta$, should contract capacity.



with D_1, capacity constraint is not binding.

with D_2, capacity constraint is binding.

— market clearing price is $(b + \lambda)$

Both demands may co-exist:

D_1 may be off-peak demand;

D_2 may be peak demand.

General rule: optimal only for peak demands to contribute to capacity costs.

MATHEMATICAL PROGRAMMING

Abstracts for Professor Shapiro's

videotapes

Mathematical Programming #1

The lecture starts with a very brief sketch of the plan of the series. The problem of concave programming is formally defined as one of maximizing a concave function subject to a set of concave inequality constraints. The consumer's allocation problem is formulated as a concave programming problem as an example.

Concave functions are defined and two problems are worked out to show that (1) a convex combination of two distinct points on any function lies on the straight line joining them and (2) all linear functions are concave.

Next the Lagrangian function corresponding to the concave programming problem is defined. The lecture ends with a mention of Kuhn-Tucker theorems in anticipation of what is to follow.

Mathematical Programming #2

The Langrangian function for any concave programming problem is recalled and Kuhn-Tucker theorems are stated. The first of these theorems states that an optimal solution is reached at the saddle point of the Lagrangian function. A saddle point has been defined and is related to the minimax criterion.

The Kuhn-Tucker theorem (2) is stated and a simple geometric proof is provided. Proof of the part of the theorem involving partial derivatives with respect to the Lagrangian multipliers is left as an exercise for students. It is emphasized that the Lagrangian with respect to λ be non-negative simply restates the constraint.

A positive value of a λ_i is interpolated as "how much the particular constraint hurts". It is also shown that at the optimum, the value of the Lagrangian is the value of the maximum: $f(x)$.

An illustrative example with a quadratic objective function and a linear constraint is worked out at the end.

Mathematical Programming #3

This lecture deals primarily with the meaning of the Lagrangian multiplier and shows that it can be regarded as one marginal value of (relaxing) the constraint to the objective function.

First, the standard utility maximization problem of a consumer subject to a budget (inequality) constraint is considered. The Kuhn-Tucker conditions are utilited and an interior solution is assumed. These first order conditions are then suitably manipulated to show that the Lagrangian multiplier associated with the budget constraint is simply the marginal utility of money.

Next the cost minimization problem of a firm is similarly treated and the Lagrangian multiplier is shown in this case to be the marginal cost.

Finally, the problem is treated in a general framework and λ is shown to equal the impact of marginally relaxing a constraint on the objective function.

In the end it is emphasized that the Lagrangian multiplier is, in essence, the shadow price of the constraint.

Mathematical Programming #4

This lecture is deveated to two specific applications of Kuhn-Tucker theory and related results developed in the earlier lectures. The first of these is from consumer behavior and deals with an individual's work leisure choice. The problem is first handled in the usual way with two constraints: (1) budget and (2) time. Next, a market constraint in the firm of minimum labor hours is introduced. The shadow price associated with this constraint is interpolated as the gain in utility achieved by relaxing the constraint marginally. Usual indifference curve diagrams are used to illustrate geometrically the important result that this shadow price would be positive only when the relevant constraint is binding.

The second example is from the theory of the firm. A form producing two different outputs is confronted with a constraint on total capital availabile, over and above the usual technological constraints. The concave programming problem is set up and Kuhn-Tucker necessary conditions are applied. It is shown as an additional result that a profit maximizing firm must always produce efficiently. The Lagrangian multiplier associated with the capital constraint is subjected to more detailed discussion. It is shown to be the marginal profitability of relaxing the capital constraint. In the concluding part, demand curves for additional capacity (starting from different levels of existing capital stock) are drawn.

Mathematical Programming #5

This lecture is related to Linear Programming (LP) as a special form of concave programming where both the objective function and the constraints are linear in form. However, at the beginning it is shown that, while Kuhn-Tucker theory can conceptually lead to the optimal solution in general in most real life problems where nonlinear functions are involved, actual computation is often very complicated. For linear programming, the problem is simple and computation is not so burdensome.

An LP problem of the maximization type is first set up algebraically. Then a numerical example involving two outputs and four constraints is given. First the constraints are shown graphically is separated diagrams. Then the transparent diagrams are superimposed to visualize the feasible area. An iso-profit line is drawn with slope equal to relative profitability of products and it is shown that evaluation of the profit function at the corner points only is sufficient to locate the optimum.

Next a similar problem is described verbally for a farmer with two crop alternatives and three resource constraints. A spectrum of cropwise profitability figures is given. The student is advised to set up the problem as an LP problem and to solve graphically for each profit regime. The maximization problem is then posed as a minimization with signs of coefficients and direction of inequalities reversed.

Different from the profit maximization problem, the standard diet problem is posed as an example of an LP problem where the objective function is to be minimized subject to a set of constraints. The problem is set up first in algebraic terms. Then numerical values are provided for the coefficients and the student is asked to go through the necessary steps to solve the problem graphically.

Mathematical Programming #6

This lecture first refers back to the diet problem which was assigned as an exercise towards the end of the previous lecture. The diet problem is posed first in algebraic form and then the numerical example is taken up. In particular the socalled "technology matrix" is elaborated. Then, as in the earlier case, the constraints are graphically represented and transparent sheets are overlaid to visualize the feasible region (which falls to the right of the "boundary of the technology set"). It is reemphasized that the optimal solution is obtained at a vertex of the feasible region.

Next, the concept of duality is introduced. The primal, is posed as a maximization problem and its dual is set up as a minimization problem. At this stage it is presented as an algebraic problem. The mechanics of setting up the dual for any given primal problem is explained. The reversal of the direction of nonequality constraints and switching of places for coefficients from objective functions to constraints is presented in a schematic form.

As an example, the dual form of the diet problem is set up as a maximization problem. An intuitive interpretation of the dual as one of a profit maximizing from selling vitamins and deciding the optimal price vector is offered.

Mathematical Programming #7

This lecture is devoted to the correspondence between the primal and dual problems in an LP problem. Three important theorems are proven. The first of these relates to existence of optimal solutions. The primal is set up as a maximization problem and the dual of it is also written. Then Lagrangian functios are constructed for the two problems. Algebraic manipulations show that the Lagrangian for the primal is the negative of the Lagrangian for the dual. The "saddle point" characterization of the optimal solution to a concave programming problem is recalled and the "minimax" result is shown. It is thereby shown that the primal has an optimal solution if and only if the dual also has an optimal solution.

The second theorem relates to the socalled complementary slackness results which follow from Kuhn-Tucker conditions. It is shown that in the primal problem any particular decision variable has a positive value only when the dual constraint associates with this variable holds as an equality. It is emphasized that this result is very helpful in practical problems of computation.

Finally, the Kuhn-Tucker conditions are utilized to show that when an optimal solution to a concave programming problem is obtained, the objective function of the primal problem has the same value as the objective function.

This lecture concludes the theoretical part of the course and reference is made to practical applications to follow in the course.

MATHEMATICAL PROGRAMMING

Lecture Notes for Professor Shapiro's

Videotapes

CONCAVE PROGRAMMING

↓

LINEAR PROGRAMMING

↓

APPLIED PROJECT

(AGRICULTURAL DEMAND FOR WATER)

$$\max. \quad y = f(x_1, x_2, \ldots, x_n)$$

$$\text{s.t.} \quad g_1(x_1, x_2, \ldots, x_n) \geqq 0$$

$$g_2(x_1, x_2, \ldots, x_n) \geqq 0$$

$$g_m(x_1, x_2, \ldots, x_n) \geqq 0$$

$$x_1 \ldots x_n \geqq 0$$

$$y = f(x)$$

$$\text{s.t.} \quad g_i(x) \geqq 0 \quad i = 1, \ldots, m.$$

$$x \geqq 0$$

$$\text{where} \quad x = (x_1, x_2, \ldots, x_n)$$

Definition

A function f(x) is concave if for any two points x^0 and x^1 and scalar t, $0 \leqq t \leqq 1$,

$$t\,f(x^0) + (1-t)\,f(x^1) \leqq f(tx^0 + (1-t)\,x^1)$$

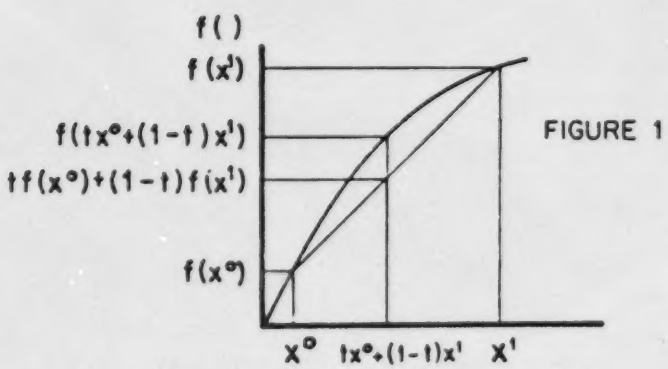
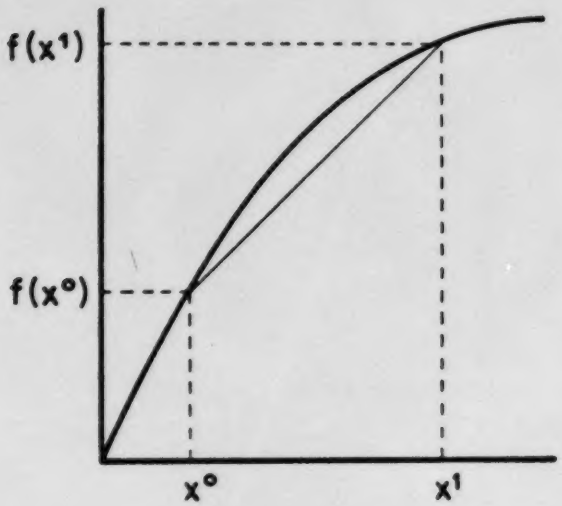


FIGURE 1

Problem 1

Show that $t\, f(x^0)+(1-t)\, f(x^1)$ represents the straight line a b in figure 1.



Problem 2

Any linear function can be written in the form $y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n$.

Show that this function is concave.

Definition Lagrangian Function

$$\Phi(x,\lambda) \equiv f(x) + \sum_{i=1}^{m} \lambda_i\, g_i(x)$$

$$\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_m)$$

Proposition 1

If $f(x)$ and $g_1(x)$ are concave for all $i = 1, \ldots, m$ then $\Phi(x, \lambda^0)$ is a concave function of x for λ^0 fixed.

$$t\Phi(x^0,\lambda^0) + (1-t)\,\Phi(x^1,\lambda^0) = t\,f(x^0) + t \sum_{i=1}^{m} \lambda_i^0 g_i(x^0)$$

$$+(1-t)\,f(x^1) + (1-t) \sum_{i=1}^{m} \lambda_i^0 g_i(x^1)$$

$$= t\,f(x^0) + (1-t)\,f(x^1) + t \sum_{i=1}^{m} \lambda_i^0\, g_i(x^0) - (1-t) \sum_{i=1}^{m} \lambda_i^0\, g(x^1)$$

But $t\,f(x^0) + (1-t)\,f(x^1) \leqq f(tx^0 + (1-t)x^1)$

and $\sum_{i=1}^{m} \lambda_i^0 (t g_i(x^0) + (1-t) g_i(x^1)) \leqq \sum_{i=1}^{m} \lambda_i^0\, g_i(tx^0 + (1-t)x^1)$

Thus,

$$t\,\Phi(x^0,\lambda^0) + (1-t)\Phi(x^1,\lambda^0) \leqq \Phi(t x^0 + (1-t)x^1, \lambda^0)$$

But $f(t x^0 + (1-t)x^1) + \sum_{i=1}^{m} \lambda_i^0\, g_i(t x^0 + (1-t)x^1) =$

$\Phi(t x^0 + (1-t)x^1, \lambda^0)$.

Kuhn - Tucker #1

An optimum solution to the concave programming problem is found by finding the values of x and λ, x°, λ° which are saddle points of the Lagrangian function.

Definition

If x°, λ° is a saddle point for the Lagrangian function

$$\Phi(x,\lambda^\circ) \leqq \Phi(x^\circ,\lambda^\circ) \leqq \Phi(x^\circ,\lambda)$$

for all $x, \lambda \geqq 0$.

$$\min_{\lambda} \max_{x} \Phi(x,\lambda)$$

Kuhn - Tucker #2

If

(i) $\dfrac{\partial \Phi(x^\circ,\lambda^\circ)}{\partial x_i} \leqq 0 \quad x_i^\circ \dfrac{\partial \Phi(x^\circ,\lambda^\circ)}{\partial x_i} = 0$ for all $i = 1,\ldots,n$

and

(ii) $\dfrac{\partial \Phi(x^\circ,\lambda^\circ)}{\partial \lambda_j} \geqq 0 \quad \lambda_j^\circ \dfrac{\partial \Phi(x^\circ,\lambda^\circ)}{\partial \lambda_j} = 0$ for all $j = 1,\ldots,m$

then x°, λ° is a saddle point of the Lagrangian function $\Phi(x,\lambda)$.

(i) Suppose $\frac{\partial \Phi}{\partial x_i} < 0$ and $x_i^\circ \frac{\partial \Phi}{\partial x_i} = 0$. Then $x_i^\circ = 0$. Therefore, in order to increase the value of Φ, it is necessary to decrease the value of x_i, but this would mean x_i would be negative -- a violation of the condition that $x_i \geqq 0$. This is illustrated in Figure 2A. Suppose $\frac{\partial \Phi}{\partial x_i} = 0$, then the second condition fulfilled for any $x_i \geqq 0$. This is illustrated in Figure 2B.

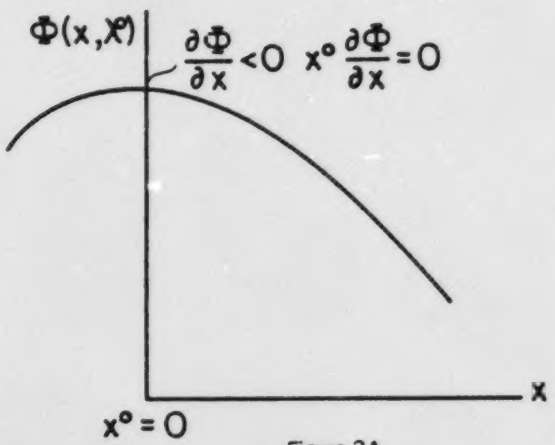


Figure 2A

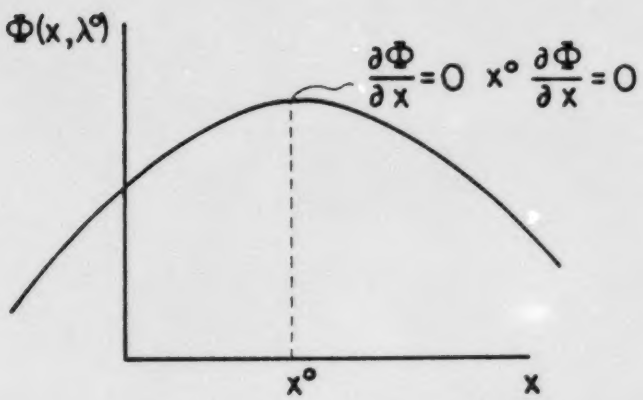


Figure 2B

$$\frac{\partial \Phi(x^\circ, \lambda^\circ)}{\partial x_i} = \frac{\partial f(x^\circ)}{\partial x_i} + \sum_{j=1}^{m} \lambda_j^\circ \frac{\partial g_j(x^\circ)}{\partial x_i} \geqq 0$$

$$x_i^\circ \frac{\partial \Phi(x^\circ, \lambda^\circ)}{\partial x_i} = x_i^\circ \left(\frac{\partial f(x^\circ)}{\partial x_i} + \sum_{j=1}^{m} \lambda_j^\circ \frac{\partial g_i(x^\circ)}{\partial x_o} \right) = 0$$

$$\frac{\partial \Phi(x^\circ, \lambda^\circ)}{\partial \lambda_j} = g_j(x^\circ) \leqq 0$$

$$\lambda_j^\circ \frac{\partial \Phi(x^\circ, \lambda^\circ)}{\partial \lambda_j} = \lambda_j^\circ g_j(x^\circ) = 0$$

$$\sum_{j=1}^{m} \lambda_j^\circ g_j(x^\circ) = 0$$

$$\Phi(x^\circ, \lambda^\circ) = f(x^\circ)$$

$$\max U(x_1, x_2)$$

$$\text{s.t. } p_1 x_1 + p_2 x_2 \leqq m$$

$$\Phi(x_1, x_2, \lambda) = U(x_1, x_2) + \lambda(m - p_1 x_1 + p_2 x_2)$$

$$\frac{\partial \Phi}{\partial x_1} = \frac{\partial U}{\partial x_1} - \lambda p_1 \leqq 0$$

$$x_1\left(\frac{\partial U}{\partial x_1} - \lambda p_1\right) = 0$$

$$\frac{\partial \Phi}{\partial x_2} = \frac{\partial U}{\partial x_2} - \lambda p_2 \leqq 0$$

$$x_2\left(\frac{\partial U}{\partial x_2} - \lambda p_2\right) = 0$$

$$\frac{\partial \Phi}{\partial \lambda} = m - p_1 x_1 - p_2 x_2 \geqq 0$$

$$\lambda(m - p_1 x_1 - p_2 x_2) = 0$$

Suppose both x_1 and x_2 are greater than zero

$$\lambda = \frac{\partial U}{\partial x_1}\Big/ p_1 = \frac{\partial U}{\partial x_2}\Big/ p_2$$

From the budget constraint

$$p_1 x_1 + p_2 x_2 = m$$

$$p_1 \frac{\partial x_1}{\partial m} + p_2 \frac{\partial x_2}{\partial m} = 1$$

What is the Marginal Utility of Money?

$$\frac{\partial U}{\partial m} = \frac{\partial U}{\partial x_1}\frac{\partial x_1}{\partial m} + \frac{\partial U}{\partial x_2}\frac{\partial x_2}{\partial m}$$

From the Optimization Conditions?

$$\frac{\partial U}{\partial m} = \lambda p_1 \frac{\partial x_1}{\partial m} + \lambda p_2 \frac{\partial x_2}{\partial m}$$

$$= \lambda \left(p_1 \frac{\partial x_1}{\partial m} + p_2 \frac{\partial x_2}{\partial m} \right)$$

$$\frac{\partial U}{\partial m} = \lambda .$$

Cost Minimization

$$\min \quad w_1 x_1 + w_2 x_2$$

$$\text{s.t.} \quad y \geqq \bar{y}$$

$$y = f(x_1 x_2)$$

$$\Phi(x_1, x_2, \lambda) = -w_1 x_1 - w_2 x_2 + \lambda (f(x_1 x_2) - \bar{y})$$

$$\frac{\partial \Phi}{\partial x_1} = -w_1 + \lambda \frac{\partial f}{\partial x_1} \leqq 0$$

$$x_1 \left(-w_1 + \lambda \frac{\partial f}{\partial x_1} \right) = 0$$

$$\frac{\partial \Phi}{\partial x_2} = -w_2 + \lambda \frac{\partial f}{\partial x_2} = 0$$

$$x_2 \left(-w_2 + \lambda \frac{\partial f}{\partial x_2} \right) = 0$$

$$\frac{\partial \Phi}{\partial \lambda} = f(x_1 x_2) - \bar{y} \geqq 0$$

$$\lambda (f(x_1 x_2) - \bar{y}) = 0$$

Suppose x_1 and x_2 are both positive

$$w_1 = \lambda \frac{\partial f}{\partial x_1} \qquad \lambda = w_1 \Big/ \frac{\partial f}{\partial x_1} \Rightarrow \lambda \neq 0$$

$$w_2 = \lambda \frac{\partial f}{\partial x_2} \qquad \lambda = w_2 \Big/ \frac{\partial f}{\partial x_2}$$

$$\lambda (f(x_1 x_2) - \bar{y} = 0$$

$$\Rightarrow \bar{y} = f(x_1 x_2)$$

From the constraint

$$\frac{\partial \bar{y}}{\partial \bar{y}} = \frac{\partial f}{\partial x_1}\frac{\partial x_1}{\partial \bar{y}} + \frac{\partial f}{\partial x_2}\frac{\partial x_2}{\partial \bar{y}} = 1$$

$$\frac{\partial c}{\partial \bar{y}} = w_1 \frac{\partial x_1}{\partial \bar{y}} + w_2 \frac{\partial x_2}{\partial \bar{y}}$$

$$\frac{\partial c}{\partial \bar{y}} = \lambda \frac{\partial f}{\partial x_1}\frac{\partial x_1}{\partial \bar{y}} + \lambda \frac{\partial f}{\partial x_2}\frac{\partial x_2}{\partial \bar{y}}$$

$$\frac{\partial c}{\partial \bar{y}} = \lambda \left(\frac{\partial f}{\partial x_1}\frac{\partial x_1}{\partial \bar{y}} + \frac{\partial f}{\partial x_2}\frac{\partial x_2}{\partial \bar{y}} \right)$$

$$\frac{\partial c}{\partial \bar{y}} = \lambda$$

Objective	Constraint	Interpretation of λ
Utility	Money	Marginal Utility of Money
Cost	Output	Marginal Cost

A General Optimization Problem

max. $f(x_1 \ldots x_n)$

s.t. $g(x_1 \ldots x_n) \leqq \bar{g}$

$$\Phi(x,y) = f(x_1 \ldots x_n) + \lambda (\bar{g} - g(x_1 \ldots x_n)$$

$$\frac{\partial \Phi}{\partial x_i} = \frac{\partial f}{\partial x_i} - \lambda \frac{\partial g}{\partial x_i} \leqq 0$$

$$x_i\left(\frac{\partial f}{\partial x_i} - \lambda \frac{\partial g}{\partial x_i}\right) = 0$$

$$\frac{\partial \Phi}{\partial \lambda} = \bar{g} - g(x_1 \ldots x_n) \geqq 0$$

$$\lambda(\bar{g} - g(x_1 \ldots x_n)) = 0$$

Suppose all the $x_i \neq 0$ and $g = \bar{g}$

From the constraints

$$\frac{\partial \bar{g}}{\partial \bar{g}} = \frac{\partial g}{\partial x_1}\frac{\partial x_1}{\partial \bar{g}} + \cdots + \frac{\partial g}{\partial x_n}\frac{\partial x_n}{\partial \bar{g}}$$

$$= \sum_i \frac{\partial g}{\partial x_i}\frac{\partial x_i}{\partial \bar{g}} = 1$$

But $\frac{\partial f}{\partial \bar{g}} = \sum_i \frac{\partial f}{\partial x_i}\frac{\partial x_i}{\partial \bar{g}}$

From the necessary conditions

$$\frac{\partial f}{\partial x_i} = \lambda \frac{\partial g}{\partial x_i}$$

$$\frac{\partial f}{\partial \bar{g}} = \sum_i \lambda \frac{\partial g}{\partial x_i}\frac{\partial x_i}{\partial \bar{g}} = \lambda \sum_i \frac{\partial g}{\partial x_i}\frac{\partial x_i}{\partial \bar{g}}$$

$$\frac{\partial f}{\partial \bar{g}} = \lambda$$

SHADOW PRICE

The lagrangian multiplier is equal to the marginal value of the constraint to the objective function: it is a price.

Work - Leisure Choice

Commodities: $x_1, \ldots, x_n$

Uses of time: labor (L), leisure (l)

$$\max \; U = U(x_1, \ldots, x_n, l)$$

s.t.

$$\sum_{i=1}^{n} p_i x_i \leqq m$$

$$m = wL$$

$$L + l = 24$$

$$\Phi(x, l, \lambda) = U(x_1, \ldots, x_n, l) + \lambda\left(w(24-l) - \sum_{i=1}^{n} p_i x_i\right)$$

$$\frac{\partial \Phi}{\partial x_i} = \frac{\partial U}{\partial x_i} - \lambda p_i \leqq 0$$

$$x_i\left(\frac{\partial U}{\partial x_i} - \lambda p_i\right) = 0$$

$$\frac{\partial \Phi}{\partial l} = \frac{\partial U}{\partial l} - \lambda w \leqq 0$$

$$l\left(\frac{\partial U}{\partial l} - \lambda w\right) = 0$$

$$\frac{\partial \Phi}{\partial \lambda} = w(24-l) - \sum_{i=1}^{n} p_i x_i \geqq 0$$

$$\lambda\left(w(24-l) - \sum_{i=1}^{n} p_i x_i\right) = 0$$

$$U = U(x, l)$$

$$px \leqq m$$

$$m = wL$$

$$L + l = 24$$

$$L \geqq 8$$

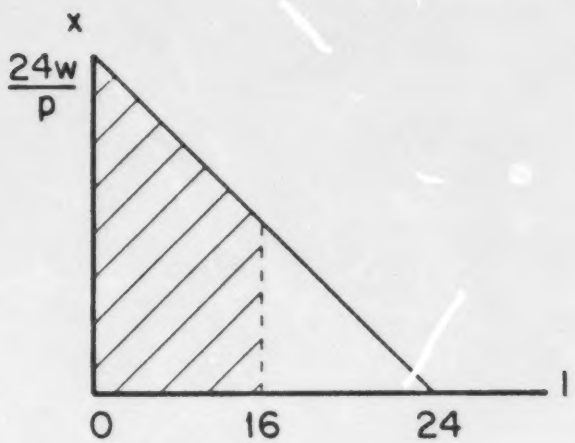
$$\Phi = U(x,l) + \lambda_1(w(24-l) - px) + \lambda_2(16-l)$$

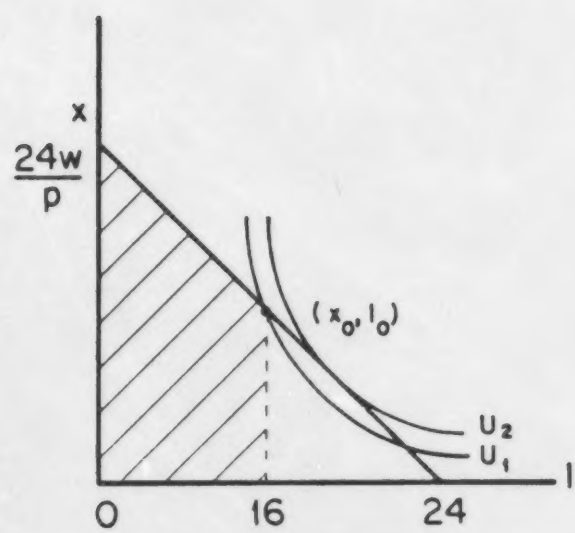
$$\frac{\partial \Phi}{\partial x} = \frac{\partial U}{\partial x} - \lambda_1 p \leqq 0 \quad x\left(\frac{\partial U}{\partial x} - \lambda_1 p\right) = 0$$

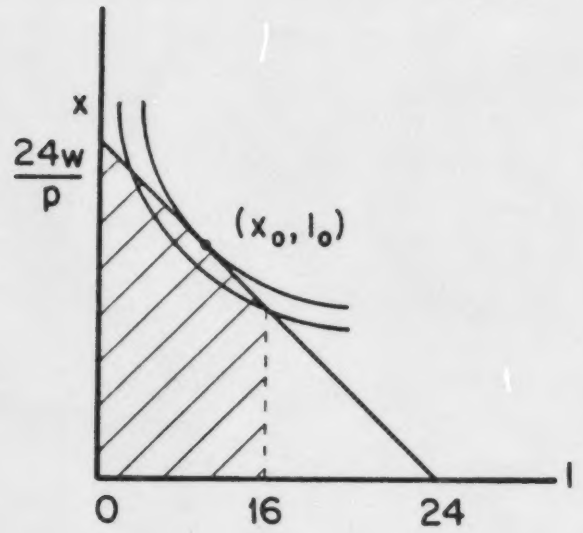
$$\frac{\partial \Phi}{\partial l} = \frac{\partial U}{\partial l} - \lambda_1 w - \lambda_2 \leqq 0 \quad l\left(\frac{\partial U}{\partial l} - \lambda_1 w - \lambda_2\right) = 0$$

$$\frac{\partial \Phi}{\partial \lambda_1} = (w(24-l) - px) \geqq 0 \quad \lambda_1(w(24-l) - px) = 0$$

$$\frac{\partial \Phi}{\partial \lambda_2} = 16 - l \geqq 0 \quad \lambda_2(16-l) = 0$$







$$q_1 \leqq f_1(L_1, K_1)$$

$$q_2 \leqq f_2(L_2, K_2)$$

$$\pi = p_1 q_1 + p_2 q_2 - w(L_1 + L_2) - c(K_1 - K_2)$$

$$K_1 - K_2 \leqq \bar{K}$$

$$\Phi = p_1 q_1 - p_2 q_2 - w(L_1 + L_2) - c(K_1 - K_2) + \lambda_1(f_1(L_1, K_1) - q_1$$

$$+ \lambda_2(f_2(L_2, K_2) - q_2) + \lambda_3(\bar{K} - K_1 - K_2)$$

PROBLEM

(i) Let $f_1(\ )$ and $f_2(\ )$ be concave. Show that the functions $g_1(q_1, L_1, K_1) = f_1(L_1, K_1) - q_1$ and $g_2(q_2, L_2, K_2) = f_2(L_2, K_2) - q_2$ are both concave.

(ii) Show that the Lagrangian function satisfies the conditions for the application of the Kuhn-Tucker conditions.

$$\frac{\partial \Phi}{\partial q_1} = p_1 - \lambda_1 \leq 0 \quad q_1(p_1 - \lambda_1) = 0$$

$$\frac{\partial \Phi}{\partial q_2} = p_2 - \lambda_2 \leq 0 \quad q_2(p_2 - \lambda_2) = 0$$

$$\frac{\partial \Phi}{\partial L_1} = -w + \lambda_1 \frac{\partial f_1}{\partial L_1}, \quad L_1\left(-w + \lambda_1 \frac{\partial f_1}{\partial L_1}\right) = 0$$

$$\frac{\partial \Phi}{\partial L_2} = -w + \lambda_2 \frac{\partial f_2}{\partial L_2}, \quad L_2\left(-w + \lambda_2 \frac{\partial f_2}{\partial L_2}\right) = 0$$

$$\frac{\partial \Phi}{\partial K_1} = -c + \lambda_1 \frac{\partial f_1}{\partial K_1} - \lambda_3 \leq 0, \quad K_1\left(-c + \lambda_1 \frac{\partial f_1}{\partial K_1} - \lambda_3\right) = 0$$

$$\frac{\partial \Phi}{\partial K_2} = -c + \lambda_2 \frac{\partial f}{\partial K} - \lambda_3 \leq 0, \quad K_2\left(-c + \lambda_2 \frac{\partial f_2}{\partial K_2} - \lambda_3\right) = 0$$

$$\lambda_1 = p_1$$

$$\lambda_2 = p_2$$

$$p_1 \frac{\partial f_1}{\partial L_1} = w$$

$$p_2 \frac{\partial f_2}{\partial L_2} = w$$

$$p_1 \frac{\partial f_1}{\partial K_1} - c = \lambda_3$$

$$p_2 \frac{\partial f_2}{\partial K_2} - c = \lambda_3$$

$$\frac{\partial \Phi}{\partial \lambda_1} = f_1(L_1, K_1) - q_1 \geq 0, \quad \lambda_1(f_1(L_1, K_1) - q_1) = 0$$

$$\frac{\partial \Phi}{\partial \lambda_2} = f_2(L_2, K_2) - q_2 \geq 0, \quad \lambda_2(f_2(L_2, K_2) - q_2) = 0$$

$$\frac{\partial \Phi}{\partial \lambda_3} = \bar{K} - K_1 - K_2 \geq 0 \quad , \quad \lambda_3(\bar{K} - K_1 - K_2) = 0$$

PROBLEM

What are the economic interpretations of λ_1 and λ_2? Is it reasonable that they should equal zero when $q_i < f_i(L_i, K_i)$ $i = 1, 2$? Explain.

$$\pi = p_1 f_1(L_1, K_1) + p_2 f_2(L_2, K_2) - w(L_1 + L_2) - C(K_1 + K_2)$$

$$\frac{\partial \pi}{\partial \bar{K}} = p_1 \left(\frac{\partial f_1}{\partial L_1} \frac{\partial L_1}{\partial \bar{K}} + \frac{\partial f_1}{\partial K_1} \frac{\partial K_1}{\partial \bar{K}} \right)$$

$$+ p_2 \left(\frac{\partial f_2}{\partial L_2} \frac{\partial L_2}{\partial \bar{K}} + \frac{\partial f_2}{\partial K_2} \frac{\partial K_2}{\partial \bar{K}} \right) - w \left(\frac{\partial L_1}{\partial \bar{K}} + \frac{\partial L_2}{\partial \bar{K}} \right)$$

$$- C \left(\frac{\partial K_1}{\partial \bar{K}} + \frac{\partial K_2}{\partial \bar{K}} \right)$$

But from the necessary conditions

$$p_1 \frac{\partial f_1}{\partial L_1} = w = p_2 \frac{\partial f_2}{\partial L_2}$$

and

$$\frac{\partial K_1}{\partial \bar{K}} + \frac{\partial K_2}{\partial \bar{K}} = 1 \text{ from } K_1 + K_2 = \bar{K}$$

Therefore

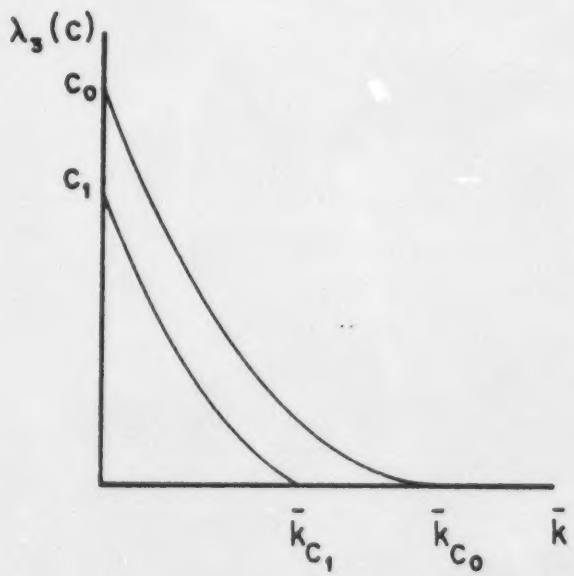
$$\frac{\partial \pi}{\partial \bar{K}} = p_1 \frac{\partial f_1}{\partial K_1} \frac{\partial K_1}{\partial \bar{K}} + p_2 \frac{\partial f_2}{\partial K_2} \frac{\partial K_2}{\partial \bar{K}} - C$$

But

$$p_1 \frac{\partial f_2}{\partial K_2} = \lambda_3 + C = p_2 \frac{\partial f_2}{\partial K_2}$$

Which implies

$$\frac{\partial \pi}{\partial \bar{K}} = \lambda_3$$



$$\max y = f(x_1, \ldots, x_n)$$

subject to

$$g_j(x_1, \ldots, x_n) \geqq 0 \quad j = 1, \ldots, m$$

Linear programming

$$f(x_1, \ldots, x_n) = \sum_{i=1}^{n} c_i x_i$$

$$g(x_1, \ldots, xn) = b_j - \sum_{i=1}^{n} a_{ij} x_i$$

$$\max \sum_{i=1}^{n} c_i x_i$$

subject to $\sum_{i=1}^{n} a_{1j} x_i \leqq b_j$

$$c' = (c_1, \ldots, cn)$$

$$A = \begin{pmatrix} a_{11} \ldots a_{n1} \\ \cdot \\ \cdot \\ \cdot \\ a_{1m} \ldots a_{nm} \end{pmatrix}$$

In matrix form

$$\max c'x$$

Subject to

$$Ax \leqq b$$

Automobile-Truck Manufacturer Capacity

	Auto	Truck
(1) Sheet metal stamping	25,000	35,000
(2) Engine assembly	33,333	16,667
(3) Automotive final assembly	22,500	0
(4) Truck final assembly	0	15,000
Profit per unit	$300 auto	$250 truck

max $300 + $250T

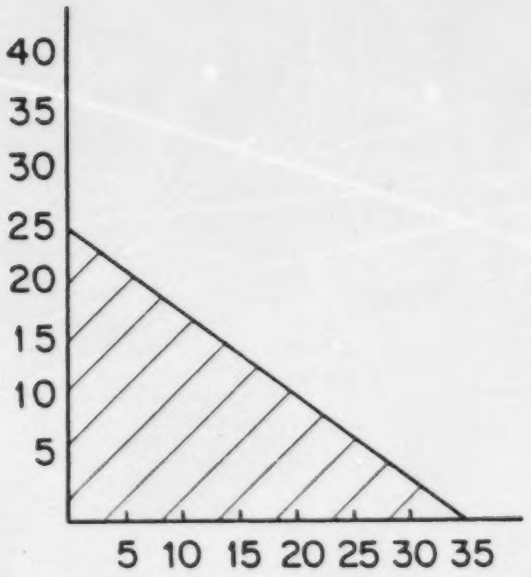
subject to

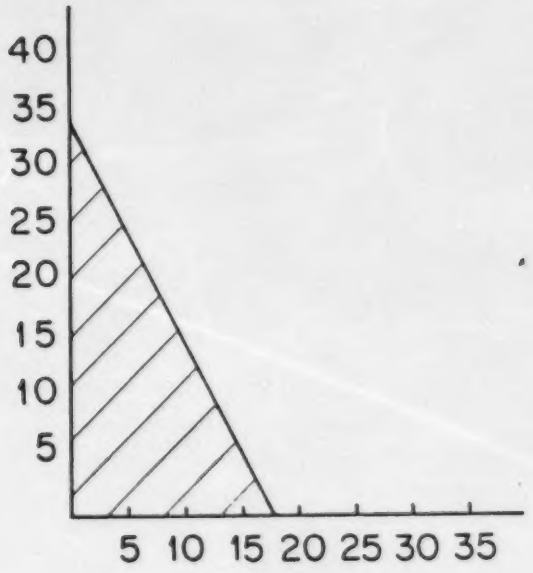
$$\frac{1}{25{,}000}A + \frac{1}{35{,}000}T \leq 1$$

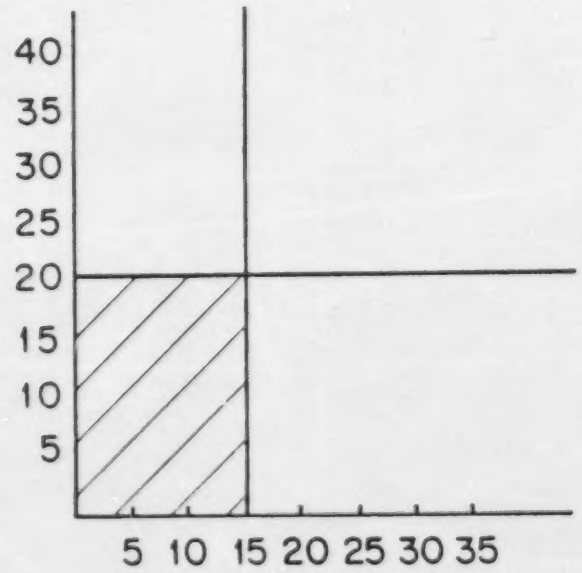
$$\frac{1}{33{,}333}A + \frac{1}{16{,}667}T \leq 1$$

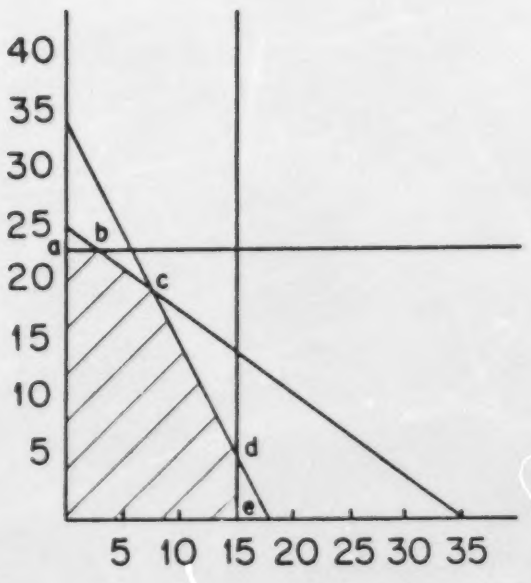
$$\frac{1}{22{,}500}A + 0 \leq 1$$

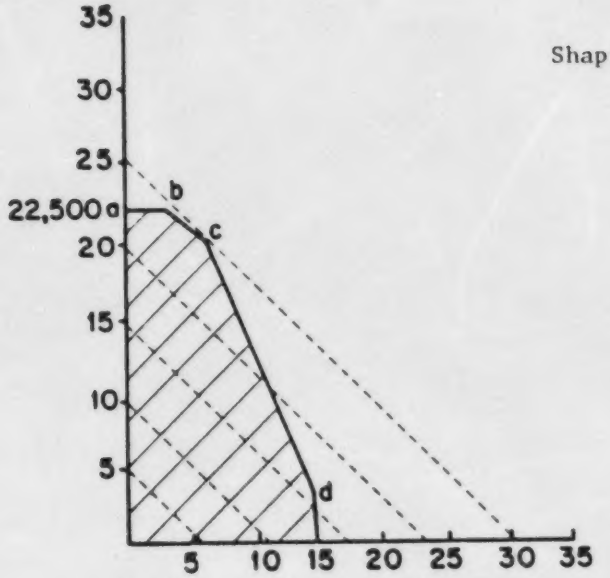
$$0 + \frac{1}{15{,}000}T \leq 1$$











A farmer grows two crops - A and B - and there are three constraints to which he must adhere. These constraints are land, labor and capital: he owns a fixed number of acres, his time is limited by the hours in the day and he owns but one tractor. If all his land is used he can plant enough to produce at most 20 units of crop A, 5 units of crop B or any linear combination between these two extremes. The capital constraint limits his production to at most 15 units of A or 15 units of B. And his labor constraint imposes a limit of 16 units of A or 8 units of B. Suppose the per unit profit for each crop were one of the following seven alternatives:

	Crop-A	Crop-B
1.	$100	$ 75
2.	$100	$100
3.	$100	$150
4.	$100	$200
5.	$100	$300
6.	$100	$400
7	$100	$450

i) Set up the linear programming problem for the profit maximizing farmer.

ii) For each of the seven alternatives listed graphically find the linear programming maximization problem.

$$\max C'x$$
$$\text{s.t.} \quad Ax \leqq b$$

$$\min -C'x$$
$$\text{s.t.} \quad -Ax \geqq -b$$

$$\min \sum_{j=1}^{n} p_j x_j$$

$$\text{s.t.} \quad \sum_{j=1}^{n} a_{ij} x_j \geqq C_i \quad i = 1, \ldots, m$$

Diet Problem

a_{11}: amount of N_1 contained in F_1

a_{12}: amount of N_1 contained in F_2

.
.
.

a_{ij}: amount of N_i contained in F_j

.
.
.

a_{mn}: amount of N_m contained in F_n

$$\min \sum_{j=1}^{n} p_j x_j$$

$$\text{s.t.} \quad \sum_{j=1}^{n} a_{ij} x_j \geqq c_1$$

$$\sum_{j=1}^{n} a_{2j} x_j \geqq c_2$$

$$\vdots$$

$$\sum_{j=1}^{n} a_{mj} x_j \geqq c_m$$

$$\min p'x$$
$$\text{s.t. } Ax \geqq C$$

Solve the diet problem given the following information:

	Beans	Beef	Requirement
price	\$0.40	\$2.00	-----
carbohydrates	4	40	160
vitamins	3	10	60
proteins	8	10	80

THE DIET PROBLEM

Foods $(F_1),(F_2),\ldots,(F_n)$

Prices $(P_1),(P_2),\ldots,(P_n)$

Nutrients $(N_1),(N_2),\ldots,(N_m)$

Requirements $(C_1),(C_2),\ldots,(C_n)$

Nutrients per unit of food

a_{11} is the amount of N_1 per unit of F_1

a_{12} is the amount of N_1 per unit of F_2

$\vdots$

a_{ij} is the amount of N_i per unit of F_j

$\vdots$

a_{mn} is the amount of N_m per unit of F_n

Quantities of Foods $x_1, x_2, \ldots, x_i, \ldots, x_n$

Minimize the cost of meals but maintain certain nutritional minima.

$$\min \; p_1 x_1 + p_2 x_2 + \cdots + p_n x_n$$

$$\text{s.t.} \quad a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \geqq C_1$$

$$a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n \geqq C_2$$

$$\vdots$$

$$a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n \geqq C_n$$

$$\min \; \sum_{i=1}^{n} p_i x_i$$

$$\text{s.t.} \quad \sum_{i=1}^{n} a_{1i} x_i \geqq C_1$$

$$\vdots$$

$$\sum_{i=1}^{n} a_{mi} x_i \geqq C_m$$

Example

Food F_1 (beans) F_2 (beef)

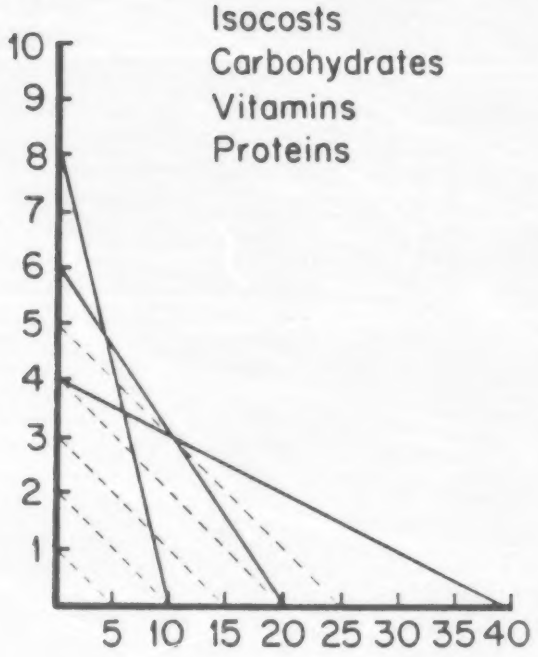
Prices p_1 40 p_2 200

Nutrients N_1 (Carbohydrates) N_2 (Vitamins) N_3 (Protein)

Requirements C_1 160 C_2 60 C_3 80

$$\min \quad 40x_1 + 200x_2$$

$$\text{s.t.} \quad 4x_1 + 40x_2 \geq 160$$
$$3x_1 + 10x_2 \geq 60$$
$$8x_1 + 10x_2 \geq 80$$



Duality

Primal

$$\max\ x_1c_1 + \cdots + x_nc_n$$

$$\text{s.t.}\quad x_1a_{11} + x_2a_{21} + \cdots + x_na_{n1} \leq l_1$$
$$x_1a_{12} + x_2a_{22} + \cdots + x_na_{n2} \leq l_2$$
$$\vdots \qquad\quad \vdots \qquad\qquad \vdots$$
$$x_1a_{1m}\ \ x_2a_{2m} + \cdots + x_na_{nm} \leq l_m$$
$$x_1 \geq 0,\ x_2 \geq 0, \ldots, x_n \geq 0$$

Dual

$$\min\ l_1\lambda_1 + l_2\lambda_2 + \cdots + l_m\lambda_m$$

$$\text{s.t.}\quad a_{11}\lambda_1 + a_{12}\lambda_2 + \cdots + a_{1m}\lambda_m \geq C_1$$
$$a_{21}\lambda_1 + a_{22}\lambda_2 + \cdots + a_{2m}\lambda_m \geq C_2$$
$$\vdots$$
$$a_{n1}\lambda_1 + a_{n2}\lambda_2 + \cdots + a_{nm}\lambda_m \geq C_n$$
$$\lambda_1 \geq 0,\ \lambda_2 \geq 0, \ldots, \lambda_m \geq 0$$

Primal

$$\max\ \sum_{i=1}^{n} x_i c_i$$

$$\text{s.t.}\quad \sum_{i=1}^{n} x_i a_{ij} \geq l_j \quad \text{for all } j = 1, \ldots, m$$
$$x_i \geq 0 \quad \text{for all } i = 1, \ldots, n$$

Dual

$$\min\ \sum_{j=1}^{m} l_j \lambda_j$$

$$\text{s.t.}\quad \sum_{j}^{m} a_{ij}\lambda_j \leq C_i \quad \text{for all } i = 1, \ldots, n$$
$$\lambda_j \geq 0 \quad \text{for all } j = 1, \ldots, m$$

In Matrix-Vector Form

$$x = \begin{pmatrix} x_1 \\ \vdots \\ x_n \end{pmatrix} \quad c = \begin{pmatrix} c_1 \\ \vdots \\ c_n \end{pmatrix} \quad \lambda = \begin{pmatrix} \lambda_1 \\ \vdots \\ \lambda_m \end{pmatrix} \quad l = \begin{pmatrix} l_1 \\ \vdots \\ l_m \end{pmatrix}$$

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & & a_{nm} \end{pmatrix}$$

Primal

$$\begin{aligned} \max \quad & x'c \\ \text{s.t.} \quad & x'A \leqq l' \\ & x \geqq 0 \end{aligned}$$

Dual

$$\begin{aligned} \min \quad & l'\lambda \\ \text{s.t.} \quad & A\lambda \geqq c \\ & \lambda \geqq 0 \end{aligned}$$

	Primal	Dual
Objective	max min	min max
Objective Coefficients	c_i p_j	l_j c_i
Constraints	l_j c_i	c_i p_j
Constraint Inequalities	$\leqq$ $\geqq$	$\geqq$ $\leqq$

Primal

$$\min \sum_{i=1}^{n} p_i x_i$$

$$\text{s.t. } \sum_{i=1}^{n} a_{ij} x_i \geq c_j \text{ for all } j = 1, \ldots, m$$

Dual

$$\max \sum_{j=1}^{m} \lambda_j c_j$$

$$\text{s.t. } \sum_{j=1}^{m} a_{ij} \lambda_j \leq p_i \text{ for all } i = 1, \ldots, n$$

Primal

$$\min\ 40 x_1 + 200 x_2$$

$$\text{s.t. } 4 x_1 + 40 x_2 \geq 160$$

$$3 x_1 + 10 x_2 \geq 60$$

$$8 x_1 + 10 x_2 \geq 80$$

Dual

$$\max\ 160 \lambda_1 + 60 \lambda_2 + 80 \lambda_3$$

$$\text{s.t. } 4 \lambda_1 + 3 \lambda_2 + 8 \lambda_3 \leq 40$$

$$40 \lambda_1 + 10 \lambda_2 + 10 \lambda_3 \leq 80$$

Concave Programming Applied to Linear Programming

Primal

$$\max \sum_{i=1}^{n} x_i c_i$$

$$\text{s.t. } \sum_{i=1}^{n} x_i\ a_{ij} \leq l_j \Rightarrow (l_j - \sum_{i=1}^{n} x_i a_{ij}) \geq 0$$

$$\Phi p = \sum_{i=1}^{n} x_i c_i + \sum_{j=1}^{m} \lambda_j (l_j - \sum_{i=1}^{n} x_i\ a_{ij})$$

Dual

$$\min \sum_{j=1}^{m} l_j \lambda_j \Rightarrow \max - \sum_{j=1}^{m} l_j \lambda_j$$

$$\text{s.t. } \sum_{j=1}^{m} a_{ij} \lambda_j \geq c_i \Rightarrow (\sum_{j=1}^{m} a_{ij} \lambda_j - c_i) \geq 0$$

$$\Phi D = \sum_{j=1}^{m} l_j \lambda_j + \sum_{i=1}^{n} x_i (\sum_{j=1}^{m} a_{ij} \lambda_j - c_i)$$

$$\Phi p = \sum_{i=1}^{n} x_i c_i + \sum_{j=1}^{m} l_j \lambda_j - \sum_{i=1}^{n}\sum_{j=1}^{m} x_i a_{ij} \lambda_j$$

$$\Phi_D = -\sum_{i=1}^{n} x_i c_i - \sum_{j=1}^{m} l_j \lambda_j + \sum_{i=1}^{n}\sum_{j=1}^{m} x_i a_{ij} \lambda_j$$

$$\Phi p = -\Phi_D$$

Remember:

A solution to the concave programming problem is a saddle point of the Lagrangian function.

Primal

$$\max_{x} \min_{\lambda} \Phi p$$

Dual

$$\max_{\lambda} \min_{x} \Phi_D$$

But since $\Phi p = -\Phi_D$

$$\max_{x} \min_{\lambda} \Phi p \Rightarrow \max_{x} \min_{\lambda} -\Phi_D \Rightarrow \min_{x} \max_{\lambda} \Phi_D$$

(1) An optimal solution to the primal problem exists, if and only if, an optimal solution to the dual problem exists.

Kuhn - Tucker Condition

$$x_i \frac{\partial \Phi p}{\partial x_i} = x_i \left(c_i - \sum_{j=1}^{m} \lambda_j a_{ij} \right) = 0$$

$$\lambda_j \frac{\partial \Phi_D}{\partial \lambda_j} = \lambda_j \left(-l_j + \sum_{i=1}^{n} x_i a_{ij} \right) = 0$$

(2) $x_i = 0$ whenever $c_i - \sum_{j=1}^{m} \lambda_j a_{ij} < 0$

$\lambda_j = 0$ whenever $\sum_{i=1}^{n} x_i a_{ij} - l_j < 0$

Recall

$$x_i \left(c_i - \sum_{j=1}^{m} \lambda_j a_{ij}\right) = 0$$

$$\lambda_j \left(-l_j + \sum_{i=1}^{n} x_i a_{ij}\right) = 0$$

From which it follows that

$$\sum_{i=1}^{n} x_i \left(c_i - \sum_{j=1}^{m} \lambda_j a_{ij}\right) = 0$$

$$\sum_{j=1}^{m} \lambda_j \left(-l_j + \sum_{i=1}^{n} x_i a_{ij}\right) = 0$$

On rearrangement

$$\sum_{i=1}^{n} x_i c_i = \sum_{i=1}^{n} \sum_{j=1}^{m} x_i a_{ij} \lambda_j$$

$$\sum_{j=1}^{m} \lambda_j l_j = \sum_{i=1}^{n} \sum_{j=1}^{m} x_i a_{ij} \lambda_j$$

which implies

$$\sum_{i=1}^{n} x_i c_i = \sum_{j=1}^{m} l_j \lambda_j$$

(3) At an optimum, the value of the primal objective function equals the value of the dual objective function.

MATHEMATICAL PROGRAMMING

Problem Set for Professor Shapiro's

Videotapes

PROBLEM SET for ECONOMICS 205C

LINEAR PROGRAMMING PROBLEMS:

1. A company manufacturing TV sets and radios has 4 major departments:

   (1) chassis

   (2) cabinet

   (3) assembly & (4) final testing

   Each department has a capacity constraint.

   Chassis capacity: 1500 TV sets or 4500 radio sets (or some combination)

   Cabinet capacity: 1000 " or 8000 " "

   Assembly capacity: 2000 " or 4000 " "

   Testing capacity: 3000 " or 9000 " "

   The contribution towards net profit is $30 per TV set and $5 per radio set. Assume that the Company can sell any quantity of either product.

   (1) Write down the optimal production planning problem of the company as an LP problem.

   (2) Set up the dual for the LP problem in (1).

   (3) Find out the solutions for both primal and dual problems.

   (4) Do your results agree with the fundamental Duality Theorem?

2. A firm produces 4 products A, B, C and D which are processed at 4 departments:

   (1) drill (2) mill (3) lathe and (4) assembly

   The productive process time (hrs) at each department is recorded below:

Product	Drill	Mill	Lathe	Assembly
A	3	0	3	4
B	7	2	4	6
C	4	4	0	5
D	0	6	5	3

The maximum available time in respective departments are:

Drill: 70 hrs.

Mill: 80 hrs.

Lathe: 90 hrs.

Assembly: 100 hrs.

Net profitability of the products (per unit) are:

A:	$ 9	C:	$14
B.	$18	D:	$11

(1) Set up the profit maximization problem of the firm as an LP and find the optimal solution.

(2) Set up the dual problem and find the optimal solution. What is your interpretation of the objective function in the dual problem?

(3) Would it be profitable for the firm to spend $3 to increase its assembly capacity by 1 hour?

3. A public welfare organization plans to spend $10,000 on a campaign highlighting the hazards of cigarette smoking. The objective is to reach the message to the maximum number of individuals with this allocated amount. The three media for campaign considered are newspaper, radio and TV. The following informations have been obtained by survey:

	Newspaper	Radio	TV
Cost per advertisement unit (a 4" x 6" ad in paper, 2 min. commercial on radio or 1 min. commercial on TV)	$ 250	$ 100	$ 2,500
No. of persons reached per unit	10,000	3,000	75,000
No. of persons in middle and upper income brackets reached (per unit)	7,000	1,000	50,000
No. of males above age 25 reached (per unit)	5,000	500	25,000

The objectives of the organization are

(1) to reach at least 300,000 persons in the area

(2) at least 50% of those persons reached be in the middle and upper income brackets.

(3) to reach at least 100,000 males above age 25.

(a) Determine the most efficient advertising program consistent with the organization's goals and limitations

(b) Assume further that the organization must place at least 7 advertisements on the radio and at least 2 on TV while no more than 100 openings on radio and 20 openings on TV are available. What is now the best advertisement plan?

4. A small farmer in Mexico has 10 acres of land and a choice of 2 field crops Wheat and Barley to cultivate.

The following are the production requirements of inputs for each crop: (per acre)

	Wheat	Barley
Fertilizers	20 kg	30 kg
Water	400 gallons	100 gallons
Labor	20 man days	50 man days

The resources available on farm are

Fertilizers	300 kg
Water	2000 gallons
Labor	400 man days

The profitability of crops are

wheat $50 per acre and barley $40 per acre

The farmer must cultivate at least 1 acre of his land. Also due to some institutional constraints he must cultivate no less than 1 acre of wheat and no more than 7.5 acres of barley.

(1) Find the optimal cropping pattern for the farmer.

(2) Can the farmer increase his profit by increasing labor by 1 man day? How much can he pay at most for this labor?

(3) Suppose that the local farmers are launching a political campaign to increase the upper limit of barley acreage to 8.5 (i.e. by 1 acre). How much, if at all, would this farmer be willing to contribute (in $) to ensure that this amendment is carried?

(4) Suppose a certain group is trying to reduce this upper limit to 5 acres (from the current level of 7.5 acres). If a move is initiated to buy off this group so that they drop their proposal how much would this farmer be willing to pay?

5. Consider the LP problem

$$\begin{aligned} \text{Max} \quad & Z = 3x_1 + 7x_2 \\ \text{s.t.} \quad & x_1 + 4x_2 \leq 20 \\ & 2x_1 + x_2 \leq 30 \\ & x_1 + x_2 \leq 8 \\ & x_1, \; x_2 \geq 0 \end{aligned}$$

Use the fundamental duality theorem to verify if (x_1=4, x_2=4) is the optimal solution to this problem. You may start with the Kuhn-Tucker Conditions but must prove all other results.

$$\begin{aligned} \text{Max} \quad & Z = 5x_1 + x_2 + 4x_3 \\ \text{s.t.} \quad & x_1 + 2x_2 + 3x_3 \leq 8 \\ & 3x_1 + x_2 + 2x_3 \leq 19 \\ & x_1, \; x_2, \; x_3, \geq 0 \end{aligned}$$

Set up the dual of this problem and solve the dual geometrically. Now use your dual solution to find the optimal solution for the primal.

7. Consider the LP

$$\begin{aligned} \text{Min} \quad & Z = 6x_1 + 4x_2 + 2x_3 \\ \text{s.t.} \quad & 6x_1 + 2x_2 + 6x_3 \geq 6 \\ & 6x_1 + 4x_2 = 12 \\ & 2x_1 - 2x_2 \leq 2 \end{aligned}$$

Set up the dual of this problem. What is the significance of the equality constraint in terms of the dual? Explain.